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# **RAPID SITE PREPARATION TECHNIQUES FOR VTOL AIRCRAFT**

**PART I General Development of Materials  
and First Order Equipment**

L. E. Doughty, Jr., et al  
LTV Aerospace Corporation, LTV Vought Aeronautics Division

Technical Report AFAPL-TR-66-116, Part I  
December 1966

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## FOREWORD

This report was prepared by the LTV Vought Aeronautics Division of LTV Aerospace Corporation, Dallas, Texas, under U. S. Air Force Contract AF33(615)-3068, BFW5(61-69DE-63406694). The work was administered under the direction of the Air Force Aero-Propulsion Laboratory, Research and Technology Division, Wright Patterson Air Force Base, Ohio. Captain A. L. Telford acted as Air Force project engineer.

The work conducted under the subject contract is divided into three parts: Part I, General Development of Materials and First Order Equipment; Part II, Optimization of Materials and Equipment; and Part III, Design and Test of Remote Site Preparation Systems. This report describes the work completed in Part I, General Development of Materials and First Order Equipment, which was conducted from 16 June 1965 through 30 April 1966.

Mr. L. E. Doughty, Jr. was the LTV project engineer. Other authors were Messrs: G. F. Thomas, Materials; D. T. Emmick, Equipment; G. Pascador, Site Thickness Criteria; G. B. Oneal, Site Size and Shape Criteria; J. E. Butler, Remote Site Preparation; and E. J. Leary, Logistics Analysis. In addition, the contributions of R. S. Rembert, S. W. McClaren, W. E. Simpkin, and P. T. Chan are gratefully acknowledged. This report was submitted by the authors on 15 September 1966.

This report has been reviewed and is approved.



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## ABSTRACT

Experimental application equipment for the preparation of remote landing and take-off sites for turbo-jet VTOL aircraft was designed, fabricated and demonstrated. Three full scale remote sites were prepared in England and the Federal Republic of Germany. Evaluation of these sites was accomplished with the P.1127 and the VJ101C-X2 aircraft respectively. These remote sites were prepared by spraying a modified chlorinated polyester resin and fiberglass roving over essentially unprepared ground. Modifications to the application equipment, further development of materials and fabrication techniques were made as a result of the experience gained in the preparation and evaluation of these remote sites.

Preliminary remote site design criteria were developed for determining site thickness, site size and shape. Experimental pads were prepared over various soil types and tested using typical wheels and tires to obtain data for determining site strength requirements. A methodology for determining site size and shape was further refined by conducting downwash flow field studies using models of the P.1127, VJ101, XC-142 and D0-31 aircraft. Dynamic pressure data obtained during remote site evaluation were correlated with model test data. Logistics support tasks for VTOL site preparation and site operation were examined.

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## SECTION I

### INTRODUCTION AND SUMMARY

#### 1. INTRODUCTION

The results of Air Force Contract AF33(615)-1092 (Reference 1) established the feasibility of using a sprayable, rapid-curing lightweight, low-cost material system for use as a remote landing and take-off site (remote site) for turbojet VTOL aircraft. Under Air Force Contract AF33(615)-2367 (Reference 2) this filled chlorinated polyester resin system was successfully modified to eliminate settling of the temperature resistant fillers. Also an automatic catalyzing method for spraying resin and catalyst simultaneously was demonstrated, a method for predicting remote site size requirements was established, and an advanced application system for preparing full-scale remote sites was defined. In addition, weight and cost comparisons showed that the Rapid-Site preparation system compared favorably with reusable membrane and metal plank remote site concepts.

The purpose of the present program is to develop an operational remote site preparation system for VTOL aircraft.

The specific objectives are:

Develop and optimize a VTOL aircraft blast-resistant material for field use.

Design and fabricate optimum field equipment for applying the optimized material.

Establish remote site preparation techniques.

Prepare full-scale remote sites for evaluation by operational VTOL aircraft.

Evaluate the remote site preparation system by analysis of data and operational results.

Establish drawings, specifications, and operational handbooks for an optimum remote site preparation system.

Prepare a field commander's handbook for the design and preparation of remote VTOL sites.

The above objectives will be accomplished over a 30-month period with four additional months for the preparation and submission of design drawings, specifications, final reports, handbooks, and the delivery of an experimental operational site preparation system.

## 2. PROGRAM SUMMARY

The program is divided into three consecutive phases of ten months duration each.

### Phase I - General Development of Material and First Order Equipment

An application system suitable for preparing field test sites for the P.1127 (English) and the VJ101C-X2 (German) VTOL aircraft will be designed and fabricated. Two remote sites will be prepared in England and one remote site will be prepared in the Federal Republic of Germany. Site design and preparation techniques will be established. Analysis, laboratory tests, data correlation and definition of problem areas for further study, test and improvement will be performed using the final results from Contract AF33(615)-2367 and the results from remote site evaluations. Improved concepts and alternate methods for site preparation will be studied and tested to reduce the weight of the overall-site preparation system and to minimize the number of personnel required to prepare a remote site. A Phase II program definition will be prepared.

### Phase II - Optimization of Materials and Equipment

Improvements of the materials and application equipment will be pursued as indicated by the results and recommendations from Phase I as defined in the Phase II program definition. Redesigned or modified equipment will be fabricated for preparing additional field test sites. Site design requirements will be established and the following sites prepared:

One site, VJ101C-X2, Federal Republic of Germany

Two sites, Balzac or Mirage III-V, France

Two sites, P.1127 and/or X-14, U.S.A.

One site, X-14, U.S.A.

Concepts for improving system performance, reducing weight, improving techniques and reducing personnel requirements will be studied, tested, and evaluated to establish the basis for the design of the final remote site preparation system. Analysis, data correlation, and definition of problem areas for final study and/or optimization will be made. Site design requirements for other VTOL aircraft, such as XV-4A (Lockheed), XV-5A (Ryan), XC-142 (LTV) and DO-31 (German) will be interpolated from data obtained. A Phase III program definition will be prepared for the design and demonstration of the final remote site preparation system.

### Phase III - Design and Test of Remote Site Preparation System

Final materials and equipment optimization will be determined by analysis and trade-off studies. An optimized experimental field site system will be designed and fabricated. Maximum usage of previous equipment will be made. Two field test sites (P.1127 type) will be prepared to demonstrate the optimized system. All test data will be analyzed and correlated to determine basic site design parameters and conditions applicable to specific and general VTOL aircraft rapid site preparation methods. Design drawings, specifications for materials and equipment, and handbooks for the operation and maintenance of equipment will be prepared. Also, a design handbook for use by forward area commanders in preparing remote VTOL sites under various terrain and weather conditions for various VTOL aircraft will be prepared. This handbook will include specific and general site design curves, graphs, and data.

#### 3. SUMMARY OF WORK ACCOMPLISHED

##### Material Formulation

A material formulation which was believed to be the most suitable considering anti-settling resistance and retention of temperature-resistant properties was selected from the twenty-seven formulations investigated under Contract AF33(615)-2367. This selection was based upon centrifuge and static aging test data as well as compatibility with the resin additive system and other selection criteria. The material consisted of a chlorinated polyester resin, high temperature additives and small percentage of a pyrogenous silica thixotropic agent.

This formulation was presented to commercial compounders for scale up batching. This was successfully accomplished with production batches of 3,800 pounds and a total quantity of approximately 90,000 pounds of compounded resin being produced.

Following full scale field trials in Europe during September and October 1965 (see Section V) several problem areas were investigated; ie. shrinkage, strength-flexibility and site fabrication methods. These investigations included the evaluation of unfilled polyester resins for non-afterburning VTOL applications, evaluation of new reinforcement methods and further development of thermal-erosion resistant polyester resin mixtures. Substantially a new materials system was developed utilizing unfilled polyester resin reinforced with woven fiberglass roving. The use of a composite construction for afterburning applications was evaluated by applying a high temperature resistant cap over a base pad prepared with unfilled resin.

##### Application Equipment Design

A resin application system was designed and fabricated using a three-quarter ton truck as the prime mover. A power take-off was incorporated for driving an air compressor and a dual resin pumping

system. The air supply was used to automatically catalyze the resin in the air dispersed resin nozzles and to operate the continuous filament fiberglass spray guns. Four Archilithics continuous filament fiberglass systems were provided. Four mobile resin tanks of 400-gallon capacity were designed and fabricated. The application equipment was designed to provide approximately 10 gallons (100 pounds) of resin per minute.

After making routine subsystem checkouts and adjustments to the application equipment, a full size site (70-foot diameter) was laid out and partially fabricated at LTV to verify the equipment operation and the site preparation technique prior to shipping the equipment to Europe.

The application equipment was used to prepare three remote VTOL sites in Europe (see Section V). As a result of this experience, a number of modifications were designed and incorporated into the equipment upon its return. Modifications were made to increase resin pumping rates, improve operational characteristics and to utilize unfilled resin and woven fiberglass roving reinforcement. The modified equipment was used to prepare a 120 foot diameter helicopter site under Contract AF33(615)-3631.

#### Site Design Requirements

##### - Site Thickness Criteria

A wheel load test facility was constructed utilizing a 15-foot diameter by 5 feet deep steel soil box and a hydraulic loading structure was provided with a maximum loading capacity of 60,000 pounds. Thirteen wheel load test pads were prepared and tested over two soil types. Average California Bearing Ratio (CBR) ranged from 2.0 to 8.6. Test pads were made using several different polyester resins in combination with sprayed fiberglass reinforcement, only, and woven fiberglass roving with sprayed fiberglass. Tire size and pressures simulated those used on the P.1127 and VJ101C-X2 aircraft. Both single and dual wheel configurations were used. Tire pressures were 100 and 200 psi. Element specimens from each test pad were tested to determine allowable tensile and bending stresses and modulus of the pad material. Similar data was obtained for specimens cut from the remote sites prepared in Europe.

##### - Site Size and Shape Criteria

A method for calculating VTOL landing pad diameter as a function of downwash and erosion characteristics which had been previously established was further refined to include the effects of multiple jets. In support of this effort literature surveys for additional soil erosion and downwash flow field information were made.

Downwash flow field studies were conducted using models of the P.1127, VJ101, XC-142 and DO-31 aircraft. Tests were also conducted to determine the feasibility of reducing site size by the use of fences at the edge of the pad. Both water table and a cold flow air nozzle

downwash test set-up were used in the fence studies. Downwash dynamic pressures and temperatures were recorded during flight operations of the P.1127 and VJ101 aircraft from VTOL sites prepared in England and Germany respectively. These data were analyzed for correlation with model test data. A study of the aerodynamic lifting forces which might be created by a VTOL aircraft over a landing pad was made.

#### Remote Site Preparation

Site layout and preparation techniques were evolved for preparing remote VTOL sites of 70 feet diameter. Small scale sites were prepared using the smaller experimental application equipment developed under Contract AF33(615)-2367. A full size 70-foot site was laid out at LTV, Dallas, and the first order equipment for Europe was used to fabricate a major portion of this site prior to shipment of the equipment to Europe.

During September 1965, two remote sites were prepared in England for evaluation with the Hawker Siddeley P.1127 aircraft. One site was 66 feet in diameter and utilized approximately 17,000 pounds of material; the other site was 50 feet in diameter and utilized about 12,000 pounds of material. Flight operations were successfully conducted from both sites.

In October 1965, one site was prepared in the Federal Republic of Germany for evaluation with the EWR Sud VJ101C-X2 airplane. This site was approximately 60 feet by 65 feet in size located adjacent to a concrete taxiway and runway. Approximately 24,000 pounds of material was used. Two hover flights were made with the VJ101C-X2 airplane. No landings or take-offs were made from this site.

#### Logistics Analysis

The logistics support tasks for VTOL site preparation and site operation were examined. A generalized VTOL Rapid Site deployment concept evaluation model was developed which reflects the primary factors dictated by VTOL operation. The studies were directed to the logistics requirements, system operational cost and examination of potential improvement areas where cost effectiveness is most sensitive.

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## SECTION II

### MATERIAL FORMULATION

#### 1. SUMMARY

The results of Air Force Contract AF33(615)-1092, Reference (1), established the feasibility of using a sprayable, rapid-curing, lightweight, low-cost material system for use as a remote landing and takeoff site for turbojet VTOL aircraft. This material system was based upon a chlorinated polyester resin system modified with temperature resistant additives and fiberglass reinforcement. The limitations of this material system and of the experimental application system developed and demonstrated during this effort were investigated under Air Force Contract AF33(615)-2367, Reference (2). The primary problem areas which were investigated were the settling and compaction of the solid materials used in the resin to obtain the jet blast thermal erosion resistance, and the elimination of hand-mixing the catalyst immediately prior to site application. Significant progress was made toward resolving these problem areas:

- a. A basic anti-settling formulation was established.
- b. An automatic catalyzing method was demonstrated.

As a result of the above progress, the early Phase I test sites used the material formulation as modified under Contract AF33(615)-2367. The principal effort of the first half of Phase I consisted of scaling-up the compounding process for the high temperature additive-filled resin. The material system developed for utilization with afterburning VTOL turbojet aircraft was subjected to full-scale field trials in Europe during the first half of Phase I of this contract. These field trials indicated the need for improvement in the following areas:

- (1) Reduction of shrinkage
- (2) Improvement in overall strength-flexibility characteristics
- (3) Improved site design and fabrication techniques

The above mentioned problem areas were investigated utilizing the experience and knowledge gained from the subject European field trials. Improvements were incorporated into the previous method of fabrication and a substantially new materials system utilizing unfilled resin reinforced with woven roving was evaluated.

#### 2. MATERIAL SELECTION

A rapid curing, thermal-erosion resistant material was developed under Contract AF33(615)-1092, Reference (1). This system was successfully demonstrated by tests with the APL J85-GE5 afterburning jet

test facility and the NASA-Ames X-14 aircraft. The above tests were conducted using material which had been prepared in the laboratory. Solid materials which had been mixed into the basic resin tended to settle out and form a tenacious sediment in the bottom of the shipping containers. The above problem was alleviated by research conducted under Contract AF33(615)-2367, Reference (2). A formulation having several orders of magnitude better settling resistance than the original formulation has been demonstrated. This was accomplished by the addition of an inorganic thixotropic agent and subsequent dispersion of the solids into the liquid resin by ball milling.

A number of antissettling agents were investigated under the above contract. These included both inorganic and organic materials. Each of these materials was evaluated at a number of concentrations. The selected formulation utilized approximately 2% Cab-O-Sil M-7, a pyrogenous silica manufactured by the Cabot Corporation.

This selection was based on the following criteria:

a. The material would impart a degree of thixotropy or other phenomena which would prevent or significantly retard the sedimentation of the high temperature additive particles.

b. The antissettling agent would not degrade the thermal-erosion resistance of the original compound.

c. The antissettling agent would not significantly degrade the flexural strength of the original formulation (combined with fibrous glass reinforcement).

d. The finished compound containing the antissettling agent would be capable of being pumped at a reasonable rate using pumps similar to those utilized on Contract AF33(615)-1092, Reference (1).

e. The antissettling agent would yield no adverse reaction with the resinous material.

Selection of the Cab-O-Sil M-7 agent was based largely on its compatibility with the original resin-additive system. However, this material was equal to or better than the other materials tests on all critical points.

Centrifuge and static aging tests were conducted under Contract AF33(615)-2367 to ascertain the degree of settling resistance imparted. These indicated that most of the materials tested yielded an appreciable degree of antissettling stabilization. Therefore, the combined criteria had to be considered.

The torch tests indicated only slight variation in thermal erosion resistance was imparted by most of the materials tested. This was due in part to the relatively low (less than 5%) antissettling agent to total material ratio.

Resistance of the selected system to afterburning jet engine exhaust impingement was demonstrated using the APL J85-GE5 jet engine test facility.

Flexural strength of laboratory specimens made from the selected formulation and 5% glass fiber compared favorably with laboratory data for the original formulation. These values ranged from 7,800 to 9,300 psi as compared with a value of 9,500 psi shown in APL-TDR-64-125, Reference (1), for the original formulation. However, specimens cut from field-sprayed sites yielded considerably lower values of 3,500 to 4,500 psi. This was probably due to lower glass content in the field applied specimens as well as the natural deterrents encountered in application of the material over rough terrain.

A trade-off of settling resistance versus viscosity was required. Figure 1 shows that the trends of the viscosity and settling resistance curves are similar. Therefore, the concentration of additive which would yield reasonable assurance of settling stability and yet not produce excessive viscosity was chosen.

It was subsequently demonstrated through pumping tests that good flow rates could be achieved with the selected formulation using 10 and 18 gpm rating Viking gear pumps.

#### a. Liaison With Resin Compounders (Large Scale Material Production)

Once the material formulation had been established in the laboratory, it was necessary to determine if the material could be manufactured on a commercial or large scale basis.

Previous experience on Contract AF33(615)-2367 indicated that open roll mills were unsatisfactory for this application. Open mills allowed severe loss of volatiles (styrene) and produced material of unpredictable composition. It is conceivable that this process could have been developed by compounding the solids with non-volatile polyester and subsequent addition of styrene. The development time required and ultimate complexity of such a process prompted investigation of alternate methods.

The laboratory specimens had been compounded using ceramic jar mills and cylindrical alundum grinding media. Consultation with commercial compounders indicated the possibility of utilizing large capacity ball mills for this purpose. However, the compounders recommended utilization of steel mills and steel grinding media. This provided better temperature control than ceramic lined mills and better grinding efficiency due to the denser grinding media.

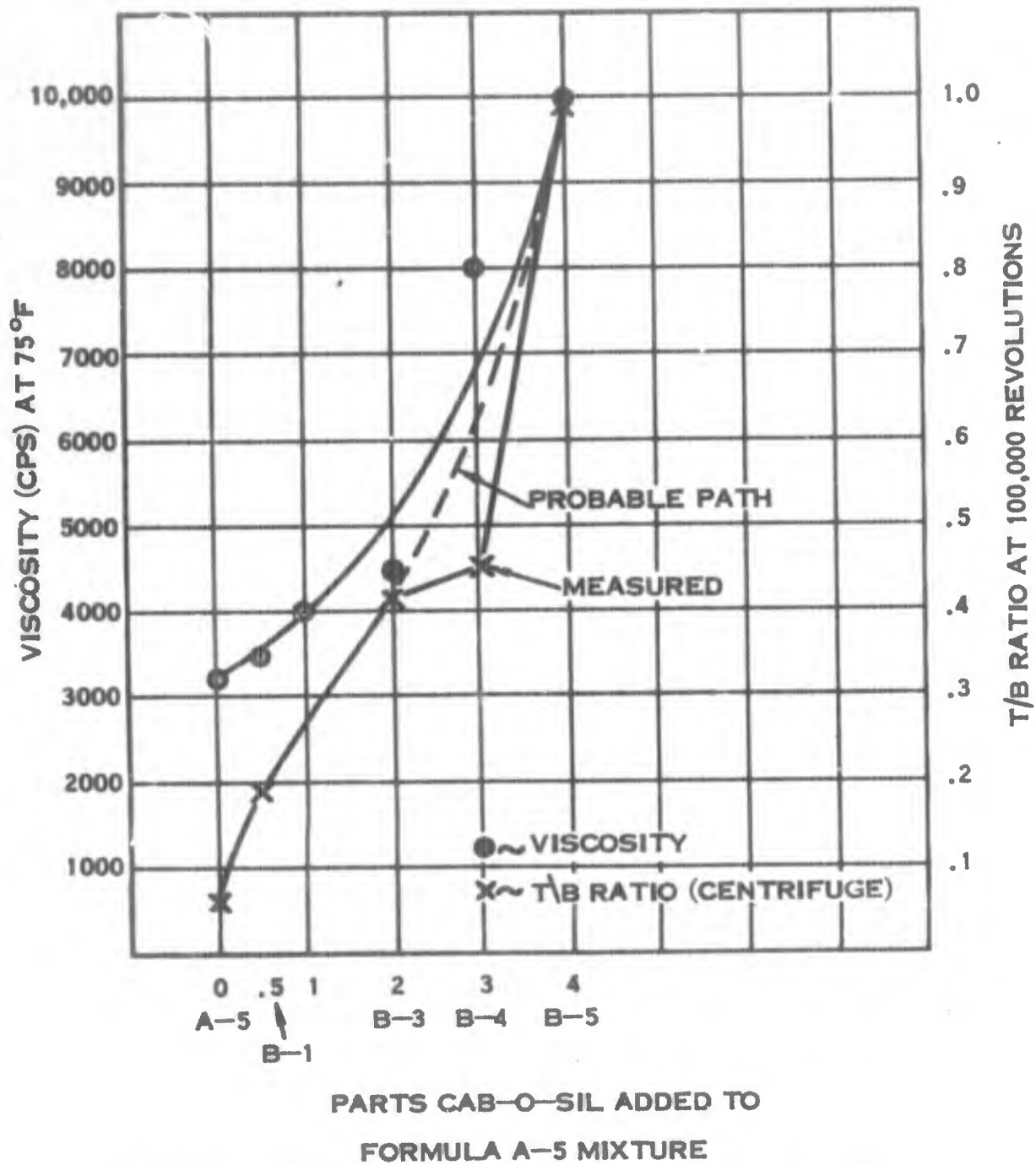


Figure 1 Viscosity and T/B Ratio Vs Parts Cab-O-Sil Added to Formula A-5

Two compounders successfully prepared the selected formulation on a commercial basis. These firms were:

Andrew Brown Company, Irving, Texas

Tropical Paint Company, Cleveland, Ohio,  
A Division of Hooker Chemical Corporation,  
Niagara Falls, New York

The Andrew Brown Company was selected to compound the material for the European portion of Phase I. This selection was based solely on timing and convenience to LTV as the finished materials produced by both firms were essentially identical.

One firm encountered some difficulty during the early portion of the scale-up operation. The energy developed during the milling operation was not removed at a sufficiently high rate, producing partial polymerization within the mill. This deficiency was remedied by increasing the cooling efficiency of the mill.

Current production batches are 3,800 pound/batch. The 60,000 pounds required for the European operation were produced in approximately three weeks of actual milling time at this rate.

#### b. Chemical and Physical Analysis

Chemical and physical analyses were developed to provide inspection criteria for the compounded resin. These analyses include:

##### Chemical

Styrene content  
Antimony oxide content  
Silica content  
Boric acid content (by difference)

##### Physical

Flexural strength  
Tensile strength  
Settling resistance  
Thermal erosion resistance  
Viscosity  
Curing rate

The procedures and requirements for both the chemical and physical analyses are detailed in Appendix IV of Reference (2).

### c. Curing Rate Tests

Simple tests were performed to determine the probable in-situ curing characteristics at the Bircham-Newton (English) site. These tests consisted of pouring 6 x 6-inch pads on the turf at Bircham-Newton. The weather was exceptionally bright and clear; therefore, some tests were performed in the shade to approximate the normally cloudy conditions. Figure 2 shows the results of these tests. It is noted that the lower MEK peroxide concentration provided slightly faster cure rates. This would indicate that the higher percentage has exceeded the amount required for this particular promotion-temperature condition. However, since the total time involved in each case was very short and the data somewhat fragmentary, no great significance should be applied to this phenomenon. Taken collectively, these curves agree in general with the data collected at LTV prior to the European operation, Figures 3 and 4.

### d. Post-European Reduction of Shrinkage

Polyester resins have relatively high shrinkage during cure. This shrinkage was modified to a large extent by incorporation of high filler content (40% in the B-3-B formation used in European trials). The residual shrinkage had been observed since early field trials with a similar formulation of Moffett Field, California in 1964 (Contract AF33(615)-1092, Reference (1)).

The observed shrinkage posed no problem at that time as the edges of the site were unrestrained and no observable stresses developed. In addition, the primary site was small (25-foot diameter) and was incrementally expanded to 59 feet in diameter with a lightweight "dust skirt" only.

The European sites experienced considerable cracking. Due to shrinkage of the resin and a low percentage fiberglass reinforcement, a built-in stress was developed with sufficient magnitude to initiate cracking. Moreover, it is probable that unobserved cracks were initiated which would cause failure at applied stresses far below the ultimate values indicated by laboratory and wheel load tests. This theory appears to have been substantiated as additional cracking occurred without application of stress and with application of stresses below the predicted ultimate values.

The more significant parameters which govern the shrinkage of a reinforced resin system are as follows:

- (1) Reactivity of the resin system (curing rate)
  - (a) Promotion level at a given temperature
  - (b) Ester functionality
  - (c) Crosslinker functionality and concentration

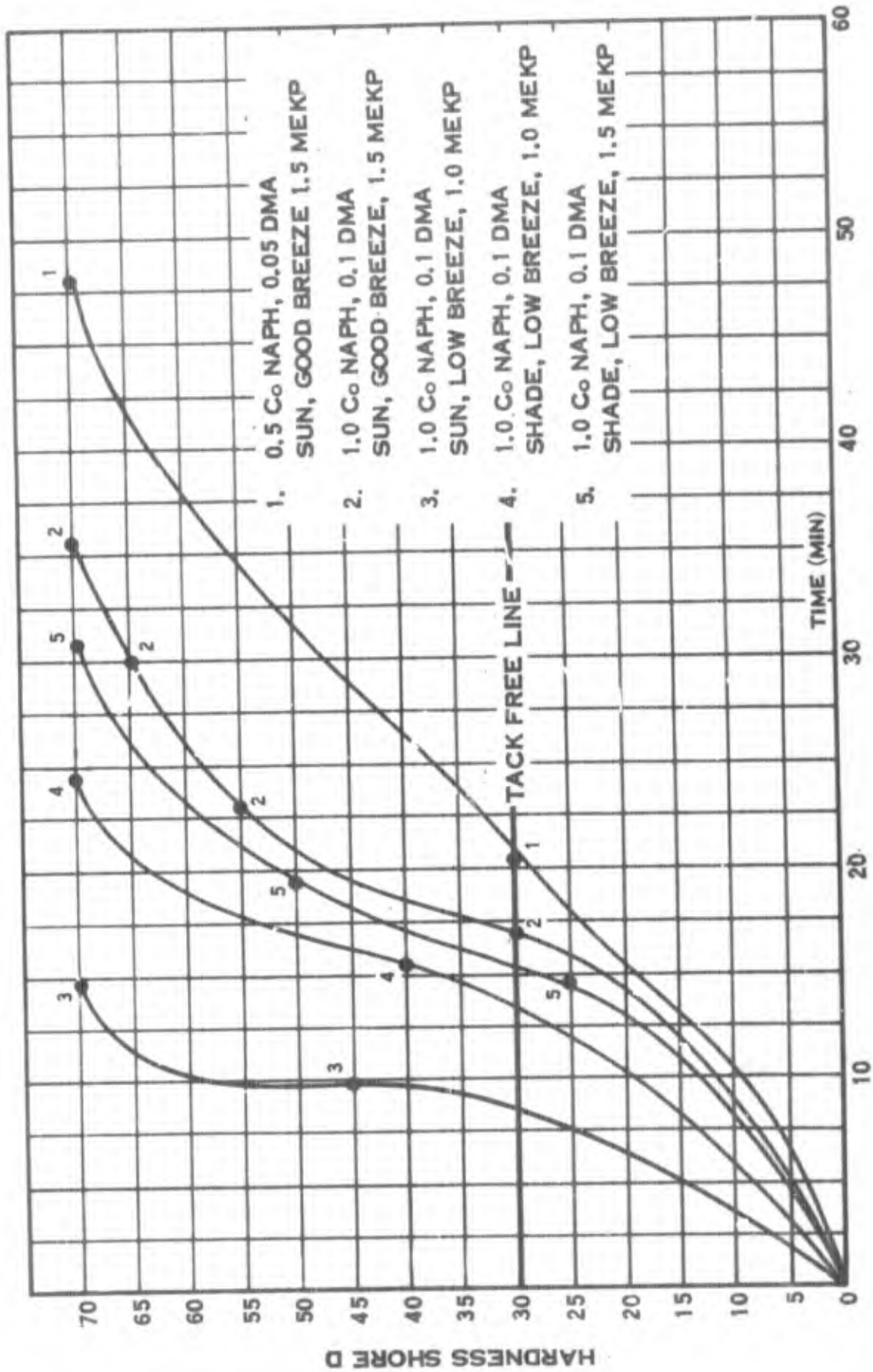


Figure 2 Curing Rate of B-3-B at Birchem-Newton Site

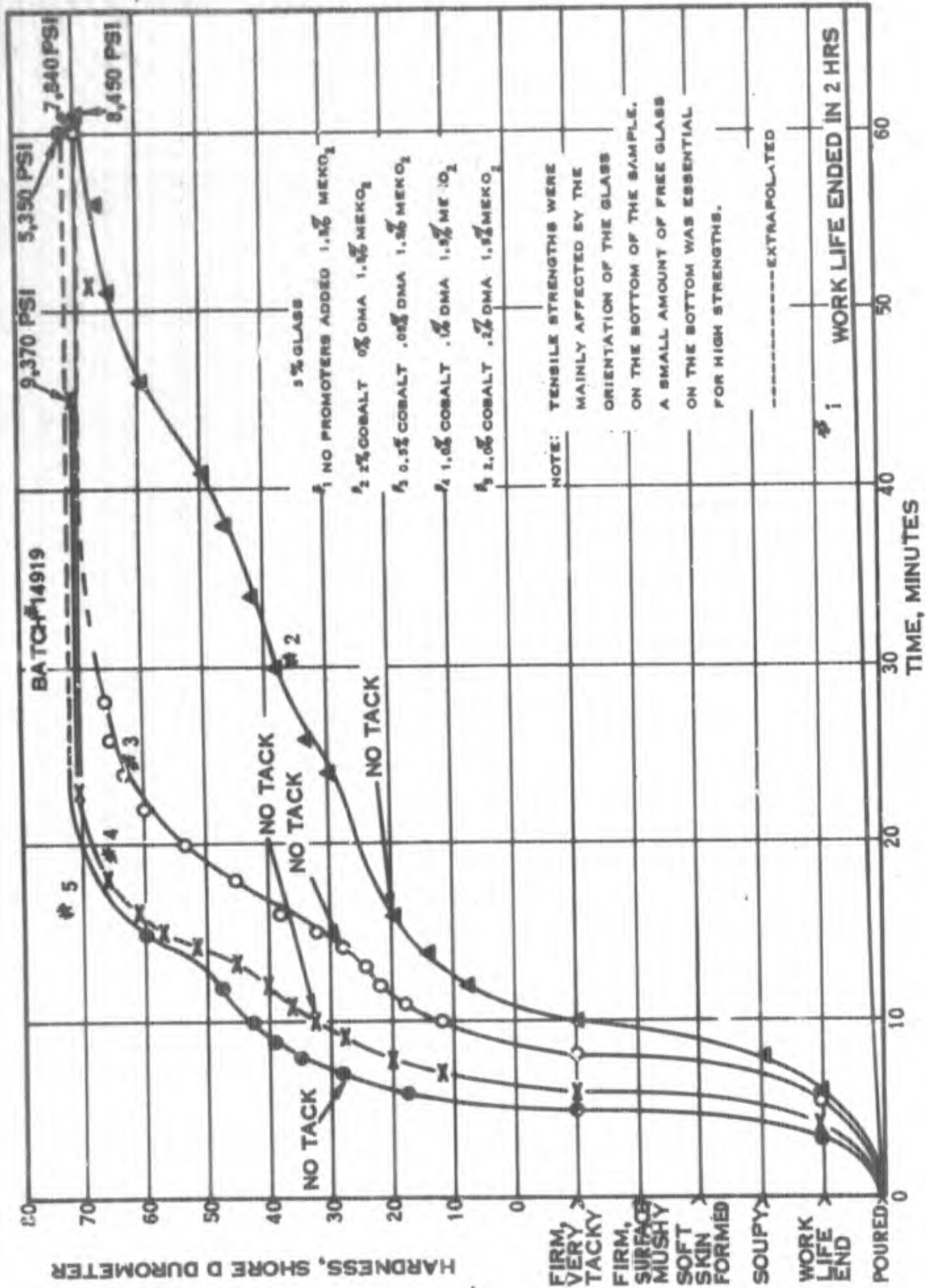


Figure 3 Curing Rate of B-3-B at 77°F

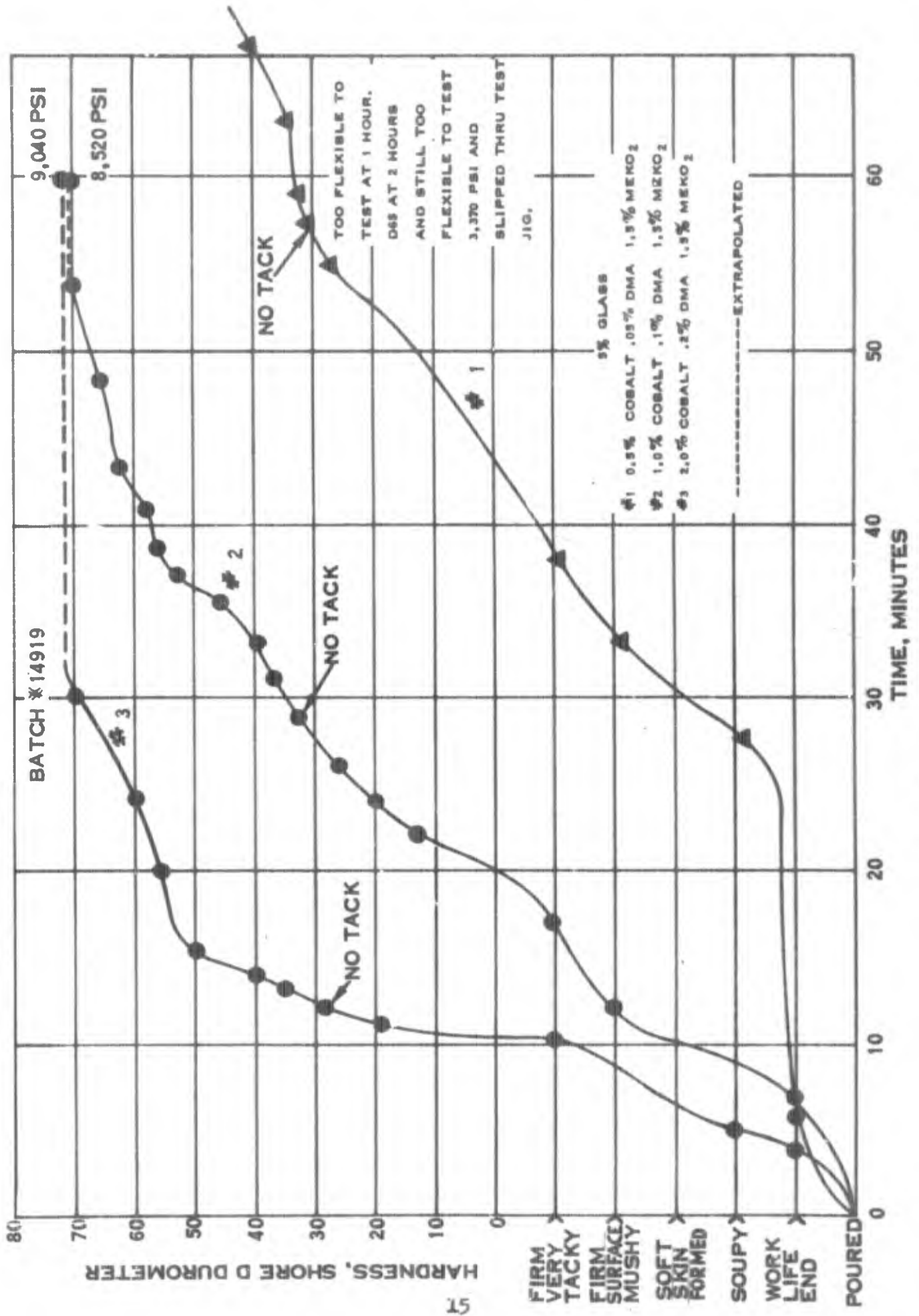


Figure 4 Curing Rate of B-3-B at 40°F

(2) Bulk filler concentration

(3) Fibrous filler (reinforcement) concentration

Of these parameters, the increased concentration of fibrous reinforcement appears to be the most effective singular deterrent to shrinkage. An increase in bulk filler concentration decreases shrinkage to a lesser extent and inhibits the ability of the system to accept higher percentages of fibrous reinforcement. Therefore, the overall effectivity of filler-reinforcement systems in shrinkage reduction is highest at high reinforcement concentrations and, as a consequence thereof, at lower bulk filler concentrations.

The effect of resin reactivity on shrinkage, while less than reinforcement concentration, is still significant.

By varying the promotion level of the system and performing the experiments isothermally, the effect of rapid versus less-rapid cure was determined. Formula B-3-B was selected for this experiment to provide a realistic reference for future studies. It was shown that the more rapid curing rates tended to produce somewhat more shrinkage than less rapid ones.

The exact functionality and concentration of the polyester and crosslinker systems under investigation are proprietary with the manufacturer. However, certain deductions may be made in this respect from the general literature on these material species. It is reasonable to expect that the more flexible resins contain longer chain groups between unsaturations than less flexible resins. It follows that the degree of unsaturation for a given molecular weight is likely (although not necessarily) to be lower for the longer chain groups and hence these resins should be somewhat less reactive. It can be shown that as the progression is made from Hetrion 32A to 31 to 42 that the flexibility (manufacturer's data) increases while the shrinkage decreases.

#### e. Shrinkage Apparatus and Procedure

The test apparatus consisted of an aluminum mold with mechanical linkage to an electrical potentiometer which converted mechanical movement, initiated by shrinkage of the plastic, into an electrical signal. This electrical current was used to excite a recorder which was calibrated to measure shrinkage directly in inches. A mechanical key was used in one end of the mold to prevent shrinkage from both ends, thus permitting all shrinkage to accumulate at the end of the mold on which the mechanical linkage to the potentiometer was located. The mold was heavily coated with a release agent to prevent adherence of the test material. The test apparatus is shown in Figure 5.

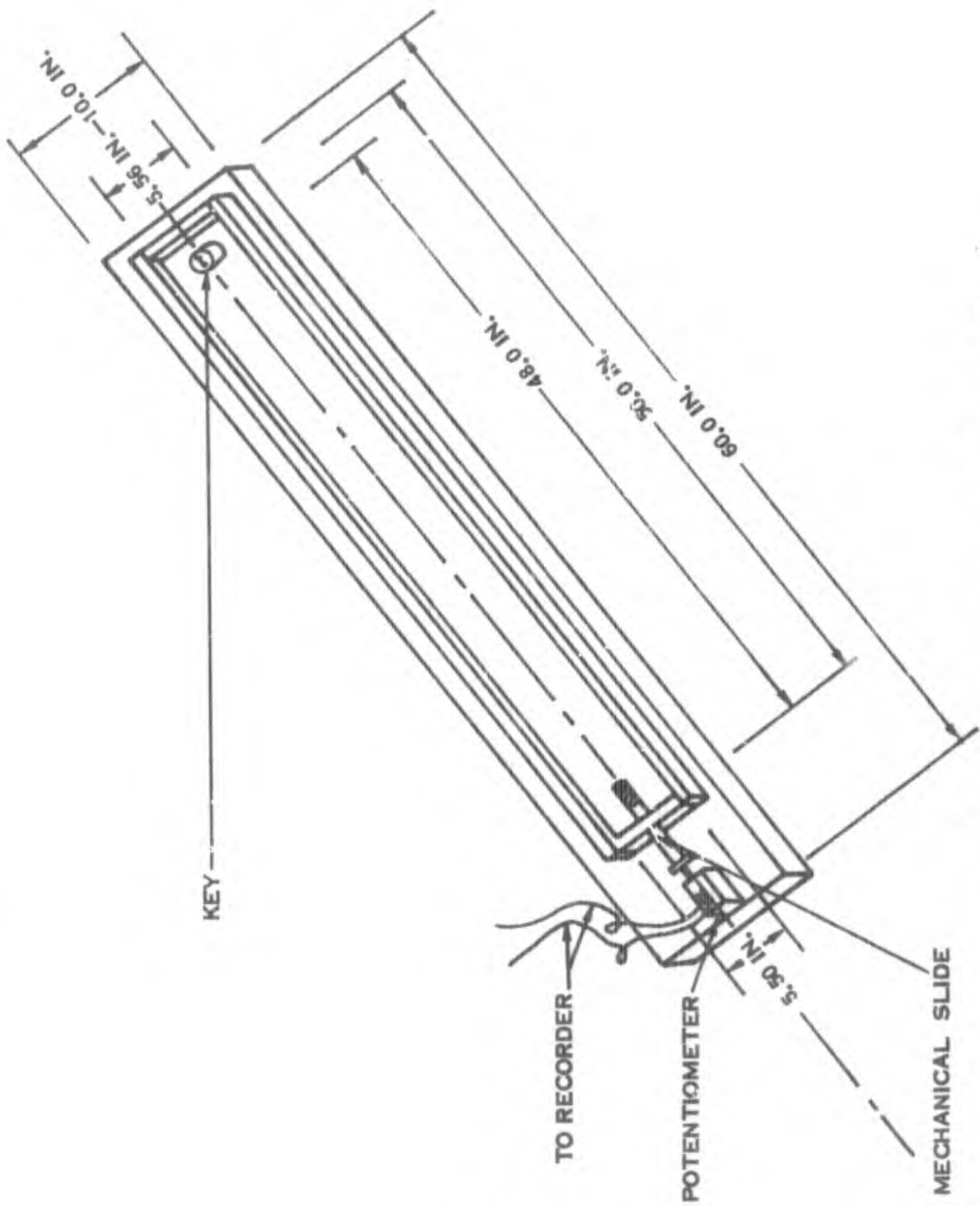


Figure 5 Shrinkage Test Apparatus - Scale 1/10

The polyester materials tested were the B-3-B resin and a number of the Hetrion polyesters; e.g., 31, 32A, 41 and 353. Resins were tested with various levels of promotion, varying both cobalt naphthenate and dimethylaniline. A standard level of catalyzation of 1.5% methyl-ethylketone peroxide was used through the entire series of tests. The amount of bulk filler contained in the base resin was varied, and the amount of glass reinforcement was also varied. Table I depicts these values and variations; also, a number of graphs are included depicting hardness, exotherm and shrinkage data.

The polyester material to be tested for shrinkage characteristics was promoted and catalyzed to the desired degree, then poured into the aluminum mold along with the desired amount of fibrous reinforcement. In all cases, care was taken to assure intimate contact of the resinous material with the sliding mechanical connection to the potentiometer. As the polyester material cured and began to shrink, the shrinkage was recorded automatically on the recorder. This curve was plotted shrinkage versus time to produce the data contained herein.

Table I contains all data in tabular form. The graphs shown in Figure 6 depict cure rate, Shore D hardness, and exotherm rates. Exotherm data are reported as the change in temperature of the specimen during the chemical reaction. Data are reported for 48-inch shrinkage specimens in Table I.

#### f. Post-European Strength and Flexibility Study

The overall strength of a given reinforced-resin system appears to be controlled most effectively by the nature and concentration of the reinforcement. However, this statement should not be construed to suggest that the strength characteristics of the resin are unimportant. It is probable that higher ultimate elongation resins tend to produce reinforced materials with higher resistance to cracking failure.

Hetrion 353 resin was selected for initial thermal-erosion resistant formulations (Contract AF33(615)-1092) because of its ability to accept large quantities of ablatives and its relatively high heat distortion temperature. This criteria still appears to be valid where extreme thermal erosion resistance is required; i.e., afterburning turbojet VTOL aircraft.

#### (1) Resin Development

The European trials indicated that the strength characteristics of the B-3-B material system based on the above resin were marginal. In addition, it appeared that some trade-off of thermal-erosion resistance in favor of increased strength-flexibility was in order.

TABLE I SHRINKAGE CHARACTERISTICS

Promotion Level			Type Bulk Filler	% Bulk Filler	Type Reinforcement	Reinforcement Pts/100	Shrinkage %
Resin Type Test No.	Cobalt Naphthenate %	Dimethyl-aniline %					
B-3-B A-2	0.0	0.0	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.04
B-3-B A-3	0.5	0.0	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.17
B-3-B A-4	1.0	0.0	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.15
B-3-B A-5	2.0	0.0	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.15
B-3-B A-6	0.5	0.05	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.25
B-3-B A-7	1.0	0.1	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.44
B-3-B A-8	2.0	0.2	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	--	--	1.30
Hetron 353 B-1	0.0	0.0	--	--	--	--	2.20
Hetron 353 B-2	0.5	0.05	H <sub>3</sub> BO <sub>3</sub>	20	--	--	1.91
Hetron 353 B-3	0.5	0.05	H <sub>3</sub> BO <sub>3</sub>	30	--	--	1.52
Hetron 353 B-4	0.5	0.05	H <sub>3</sub> BO <sub>3</sub>	40	--	--	1.21
Hetron 353 B-5	0.5	0.05	H <sub>3</sub> BO <sub>3</sub>	50	--	--	0.98
B-3-B D-2	0.5	0.05	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	PPG-533-60	3.06	0.45
B-3-B D-3	0.5	0.05	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	PPG-533-60	5.27	0.42
B-3-B D-4	0.5	0.05	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	35 6	PPG-533-60	7.85	0.23

TABLE I SHRINKAGE CHARACTERISTICS (Concluded)

Resin Type Test No.	Promotion Level		Type Bulk Filler	% Bulk Filler	Type Reinforce ment	Rein- force- ment Pts/100	Shrinkage %
	Cobalt Naph- thenate %	Dimethyl- aniline %					
32-A D-6	0.5	0.05	--	--	--	--	2.02
32-A D-7	0.5	0.00	--	--	PPG-533-60	5.25	0.354
32-A D-8	0.5	0.0	--	--	PPG-533-60	11.02	0.250
31 E-1	0.5	0.05	--	--	--	0.0	1.42
353-95% Styrene 5% C-1	0.5	0.0	--	--	--	--	2.35
42 E-2	0.5	0.0	--	--	--	--	1.04
75%-31 25%-42 E-3	0.5	0.0	--	--	PPG-533-60	11.02	None
50%-31 50%-42 E-4	0.5	0.0	--	--	PPG-533-60	17.5	None
75%-31 25%-42 E-6	0.5	0.0	--	--	PPG-533-60	14.3	0.031
75%-31* 25%-42 E-7	1.0	0.1	H <sub>3</sub> BO <sub>3</sub> Sb <sub>2</sub> O <sub>3</sub>	14 3	PPG-533-60	7.25	0.001

\* No graph available for this specimen

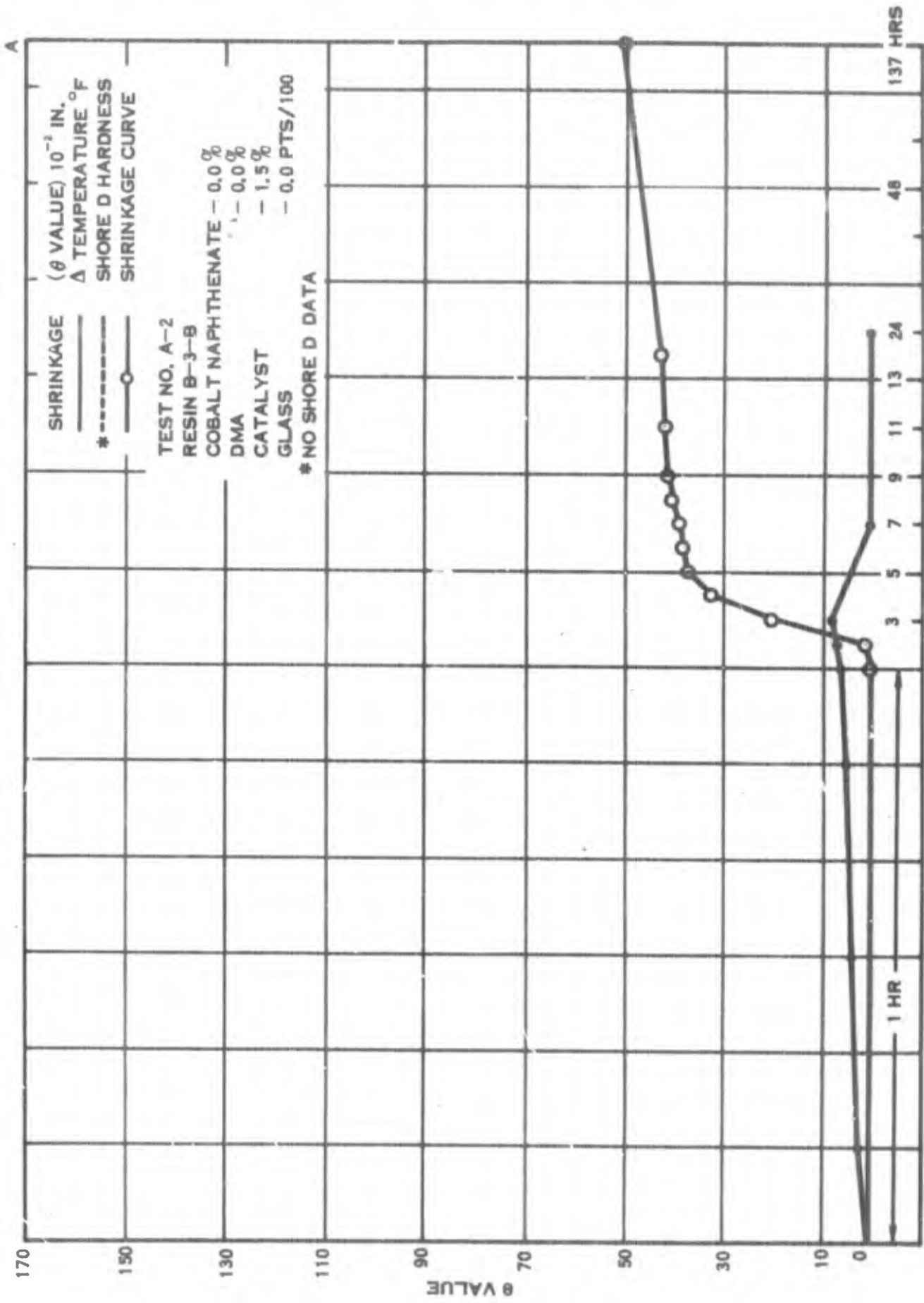


Figure 6. Shrinkage Curves (a)

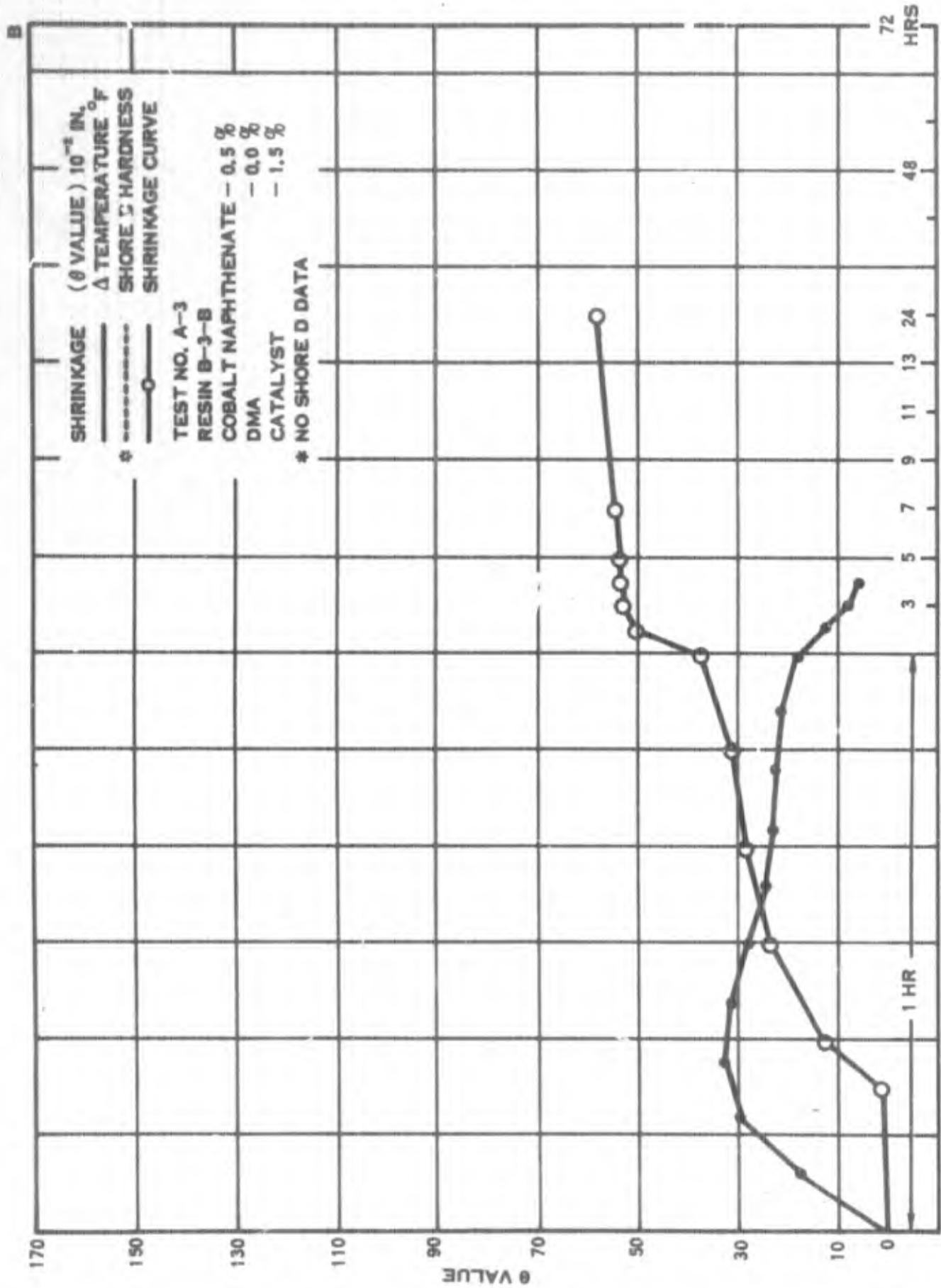


Figure 6. Shrinkage Curves (Continued) (b)

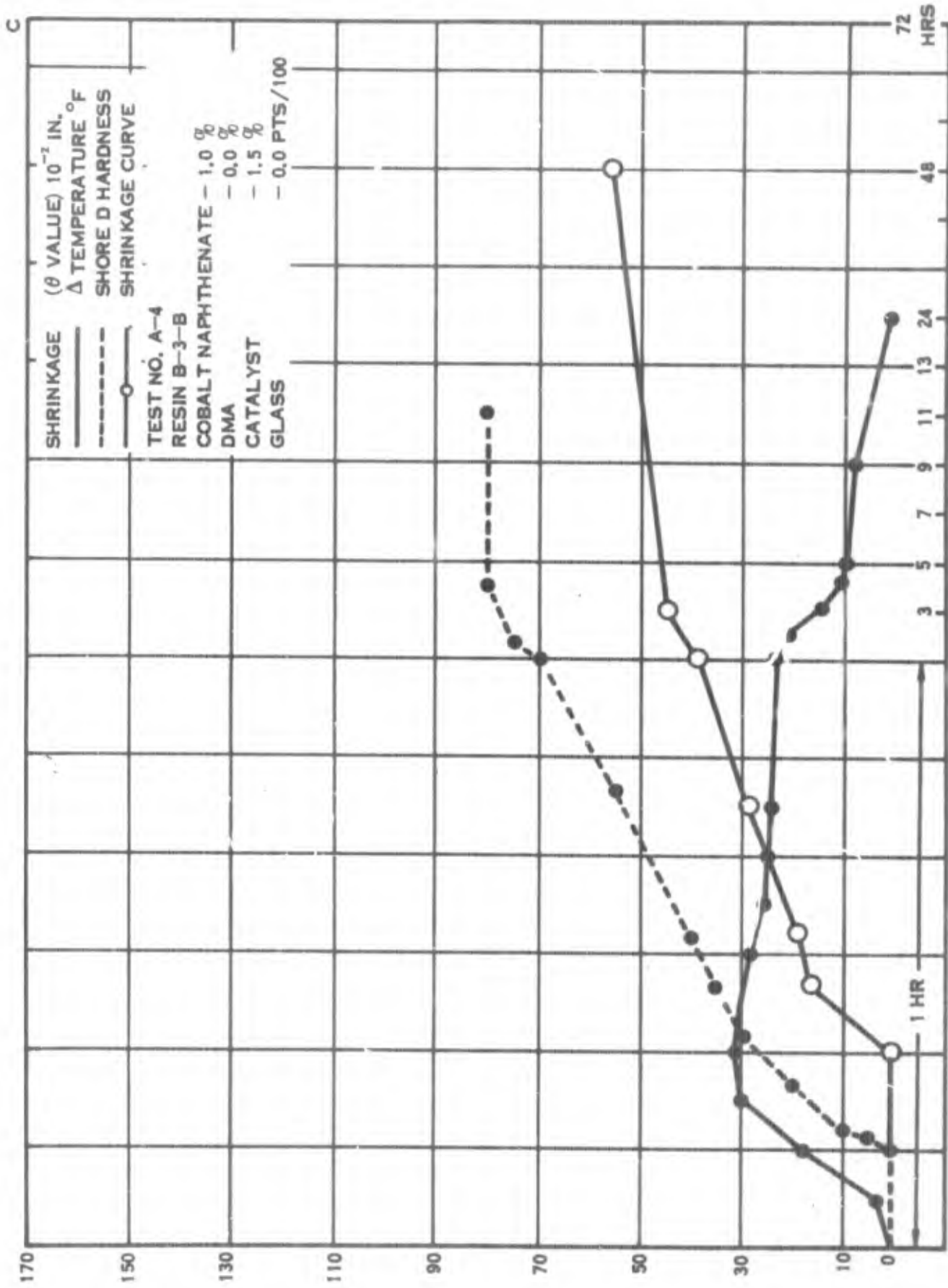


Figure 6. Shrinkage Curves (Continued) (c)

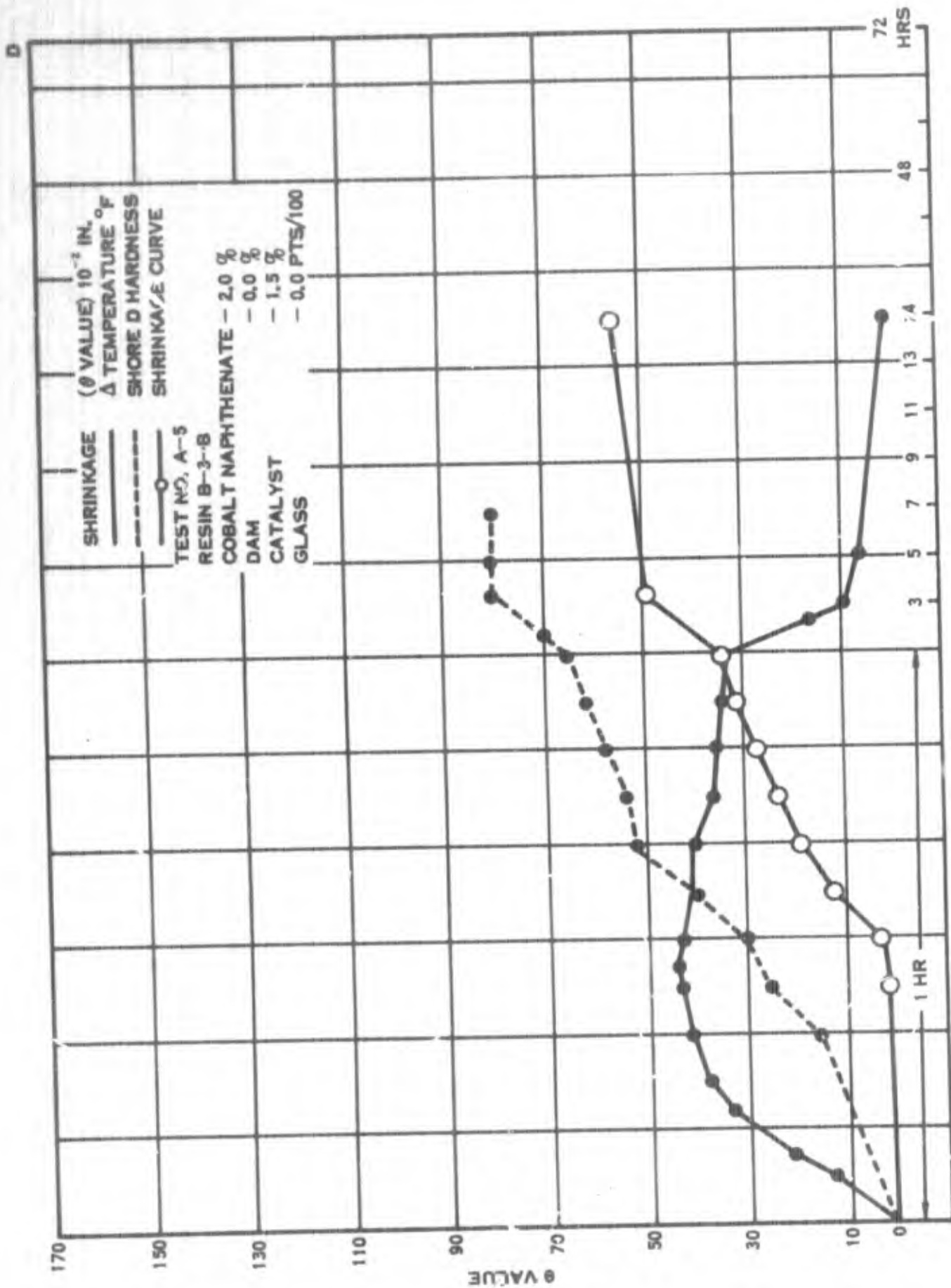


Figure 6. Shrinkage Curves (Continued) (d)

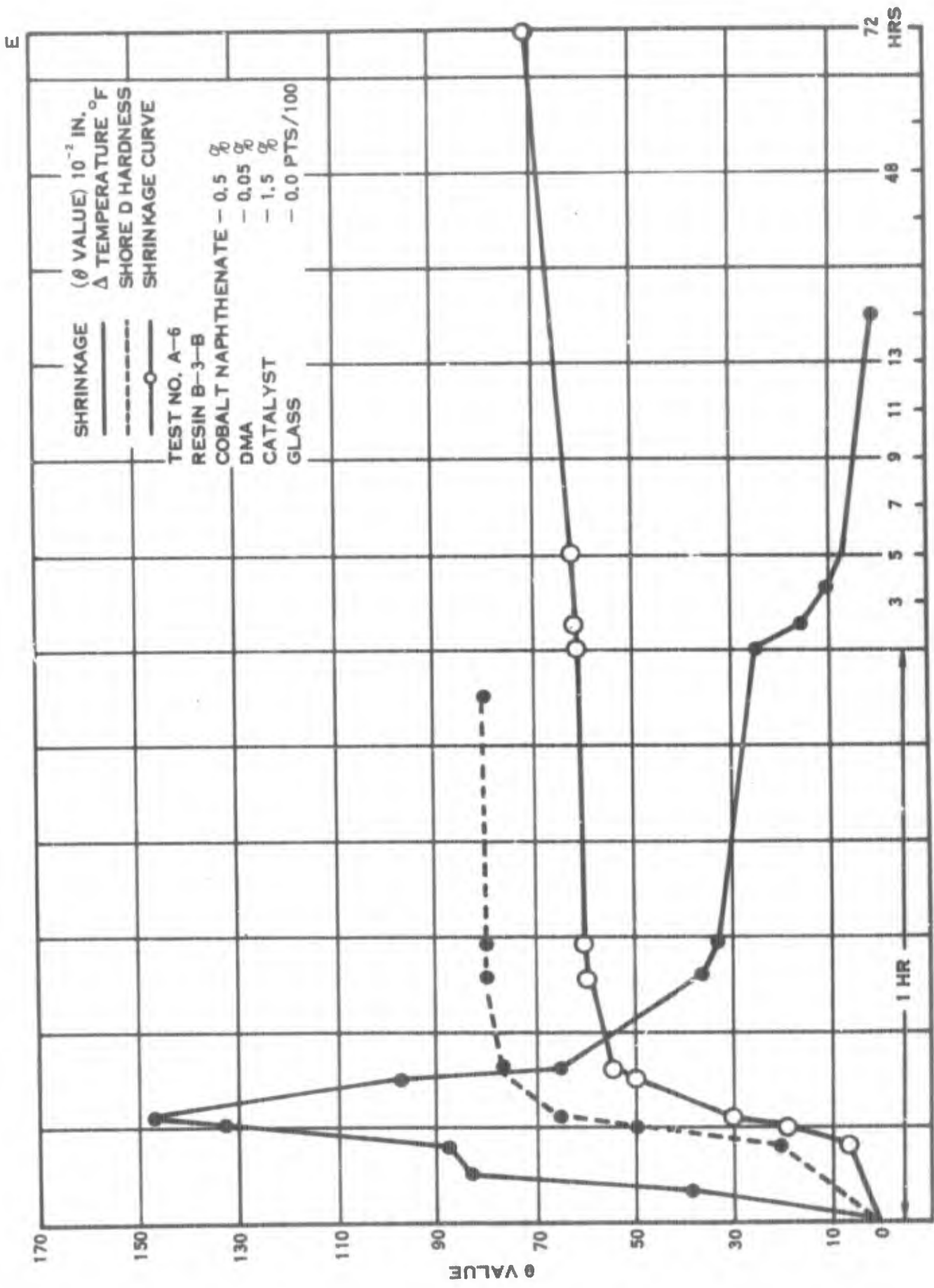


Figure 6. Shrinkage Curves (Continued) (e)

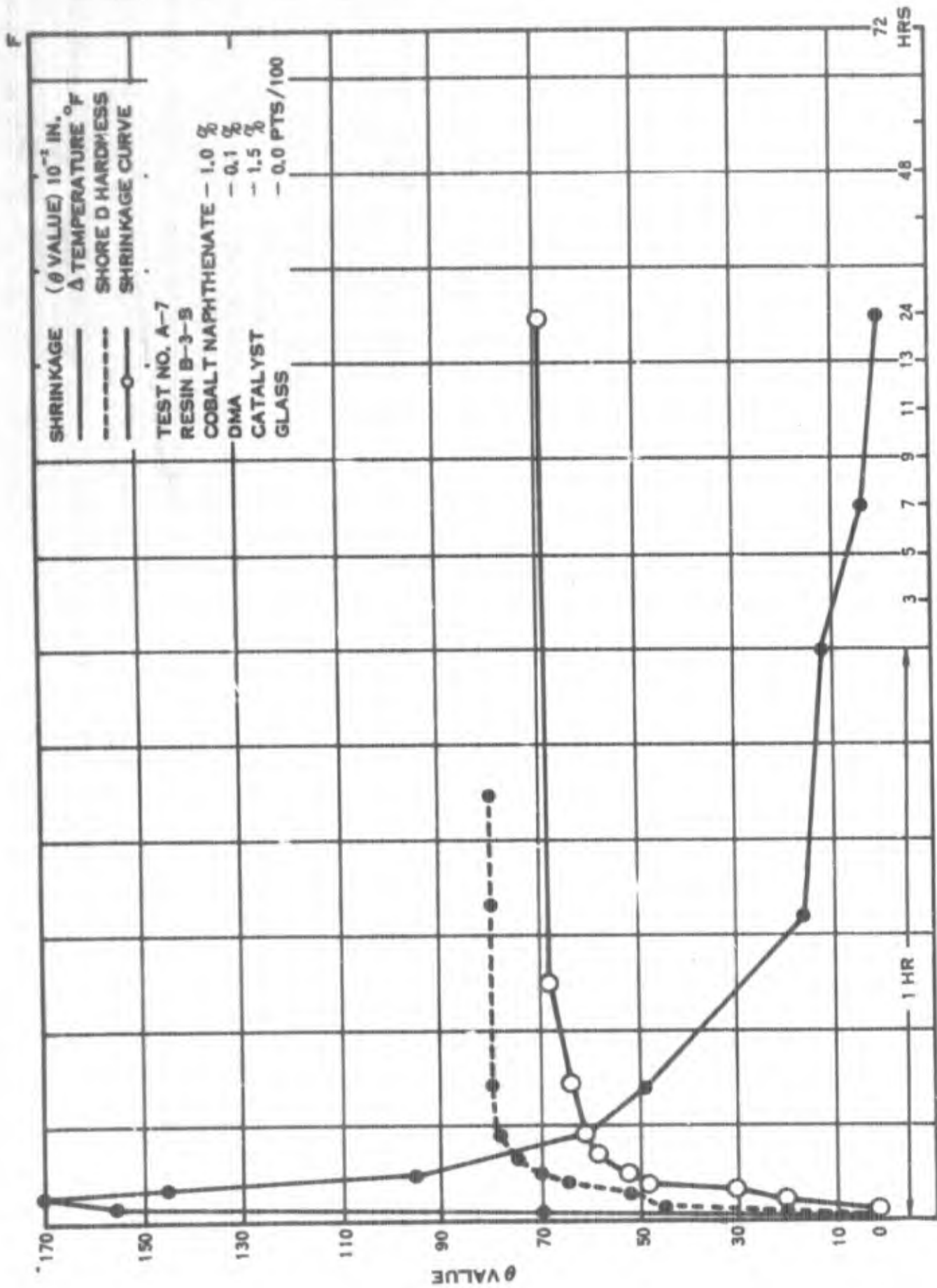


Figure 6. Shrinkage Curves (Continued) (F)

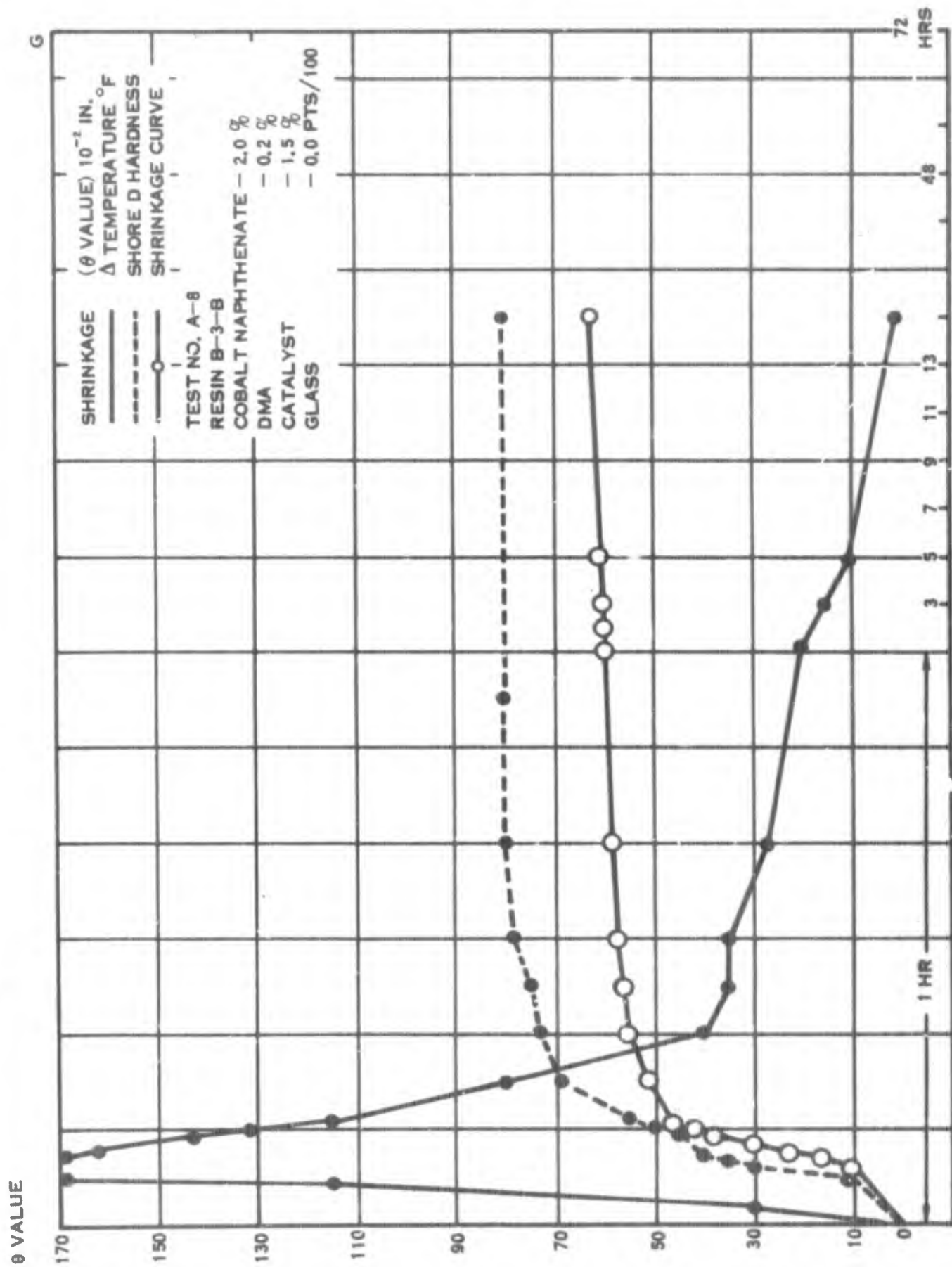


Figure 6. Shrinkage Curves (Continued) (g)

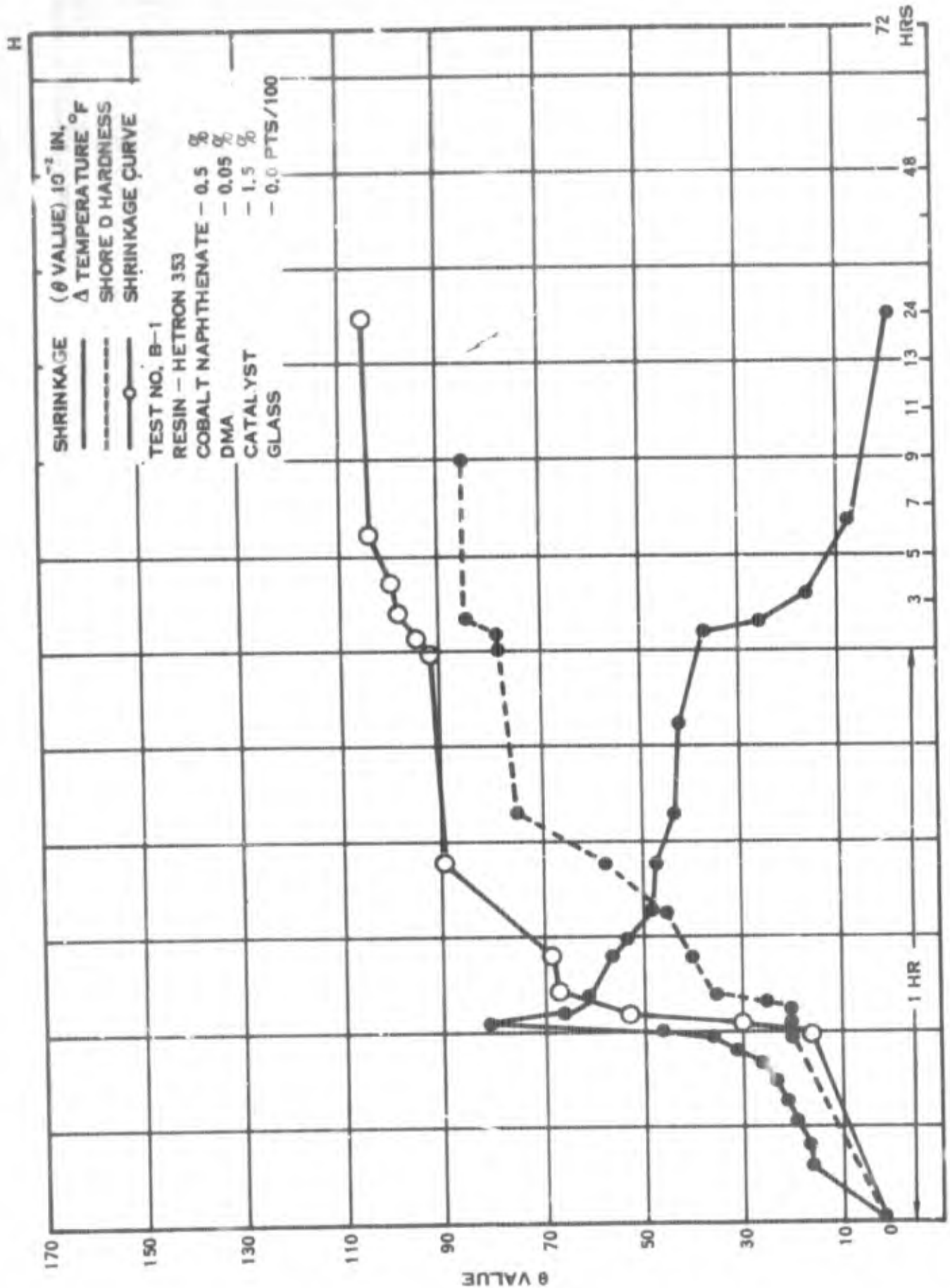


Figure 6. Shrinkage Curves (Continued) (h)

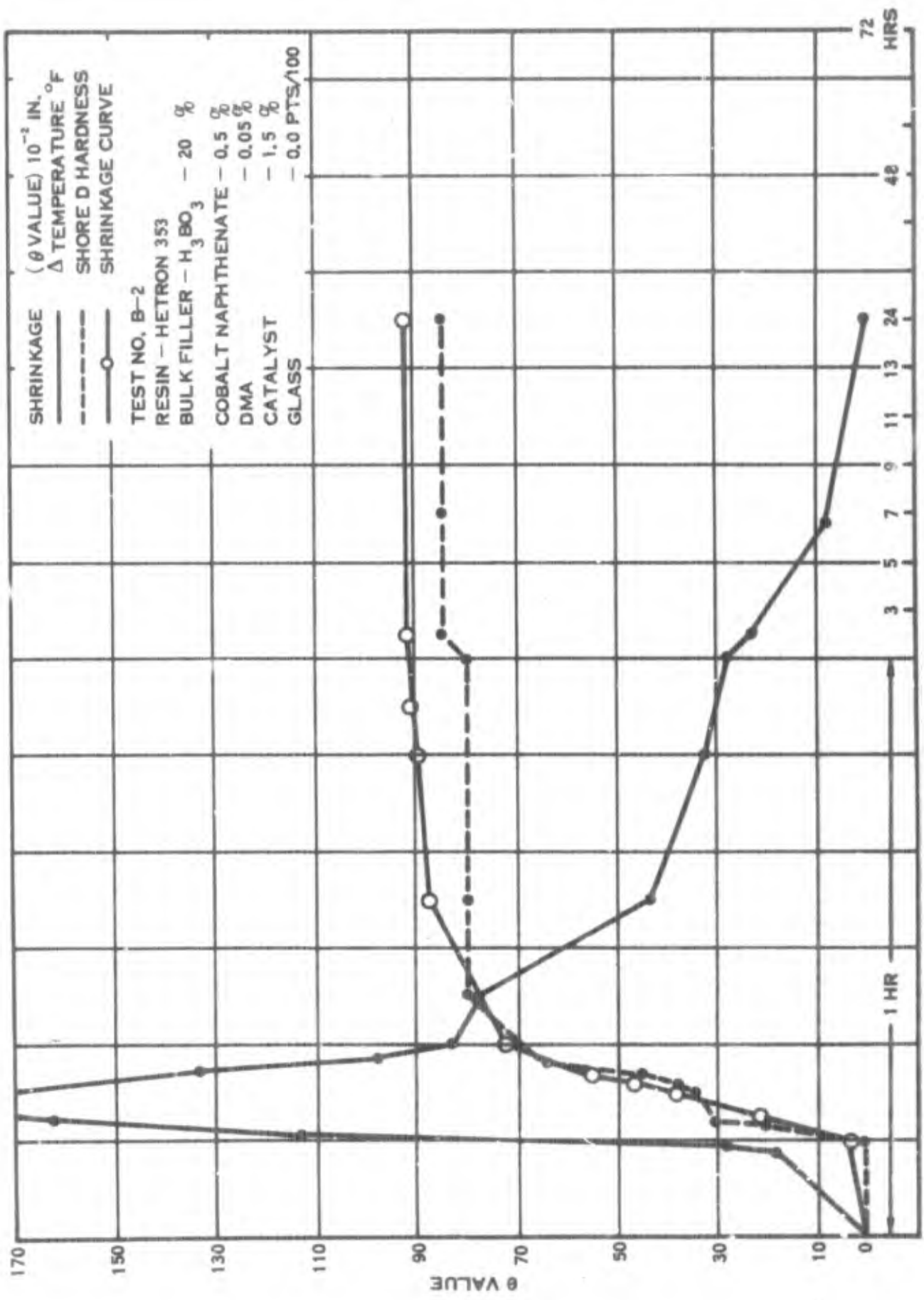


Figure 6. Shrinkage Curves (Continued) (1)

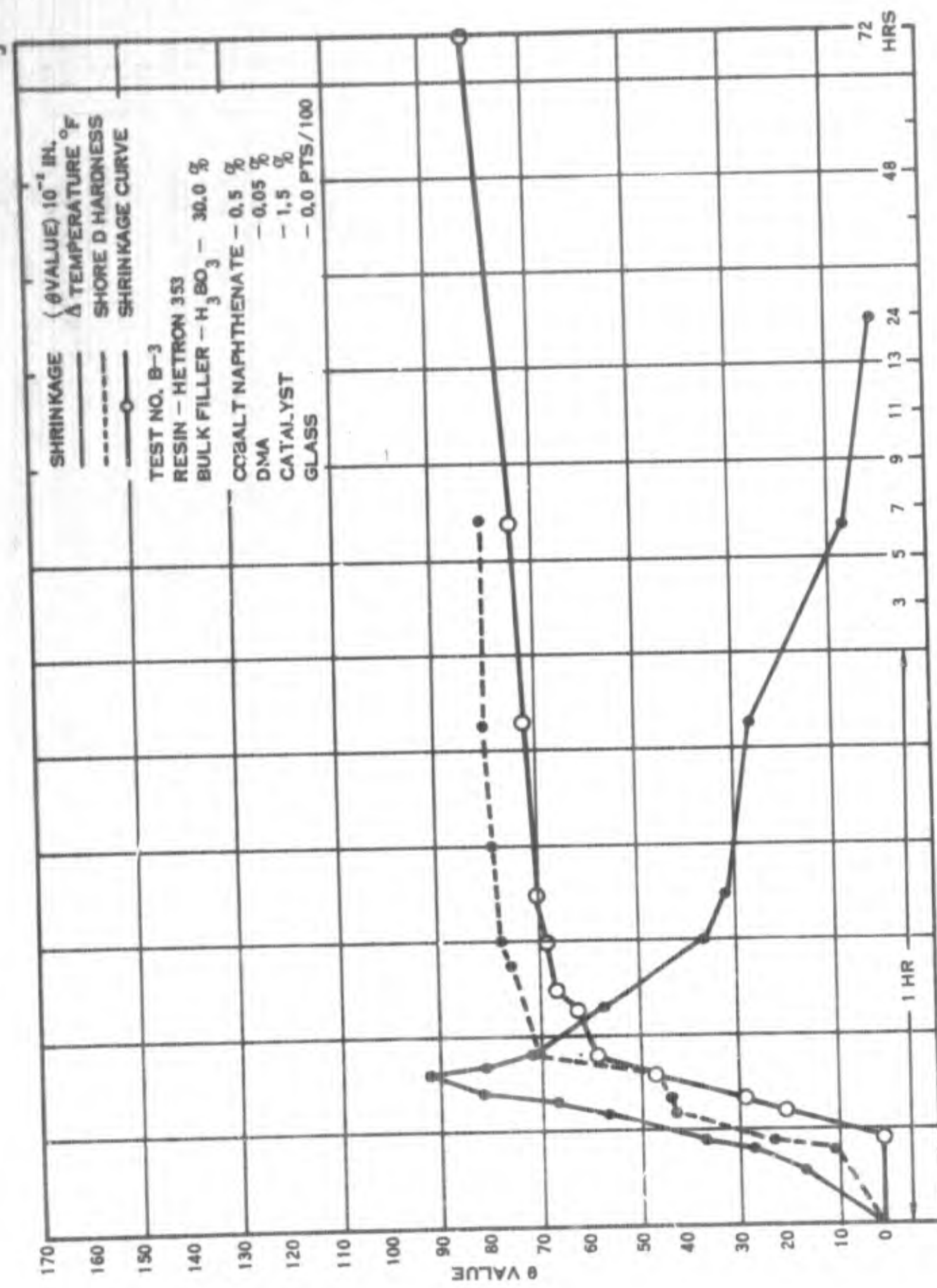


Figure 6. Shrinkage Curves (Continued) (J)

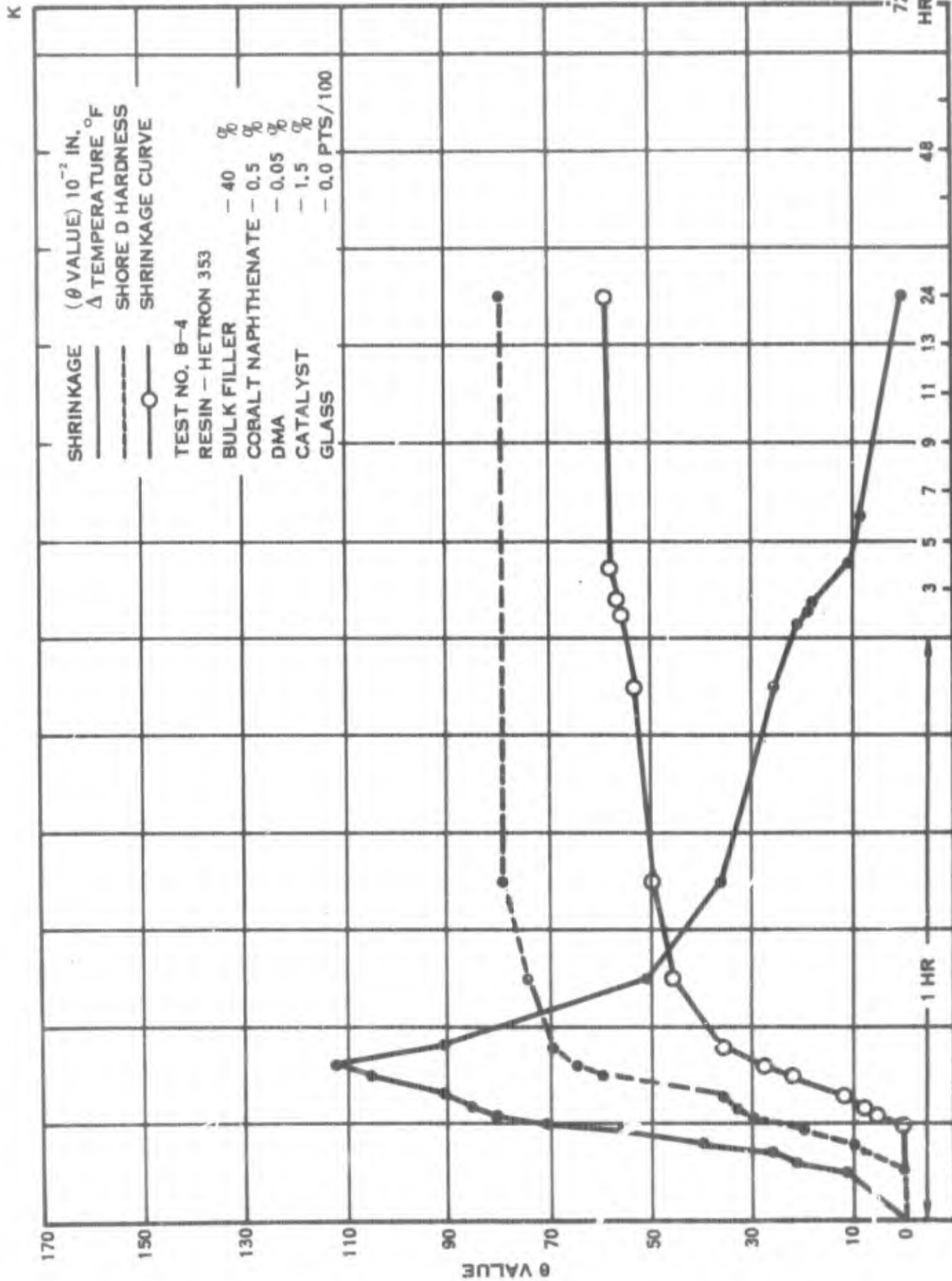


Figure 6. Shrinkage Curves (Continued) (k)

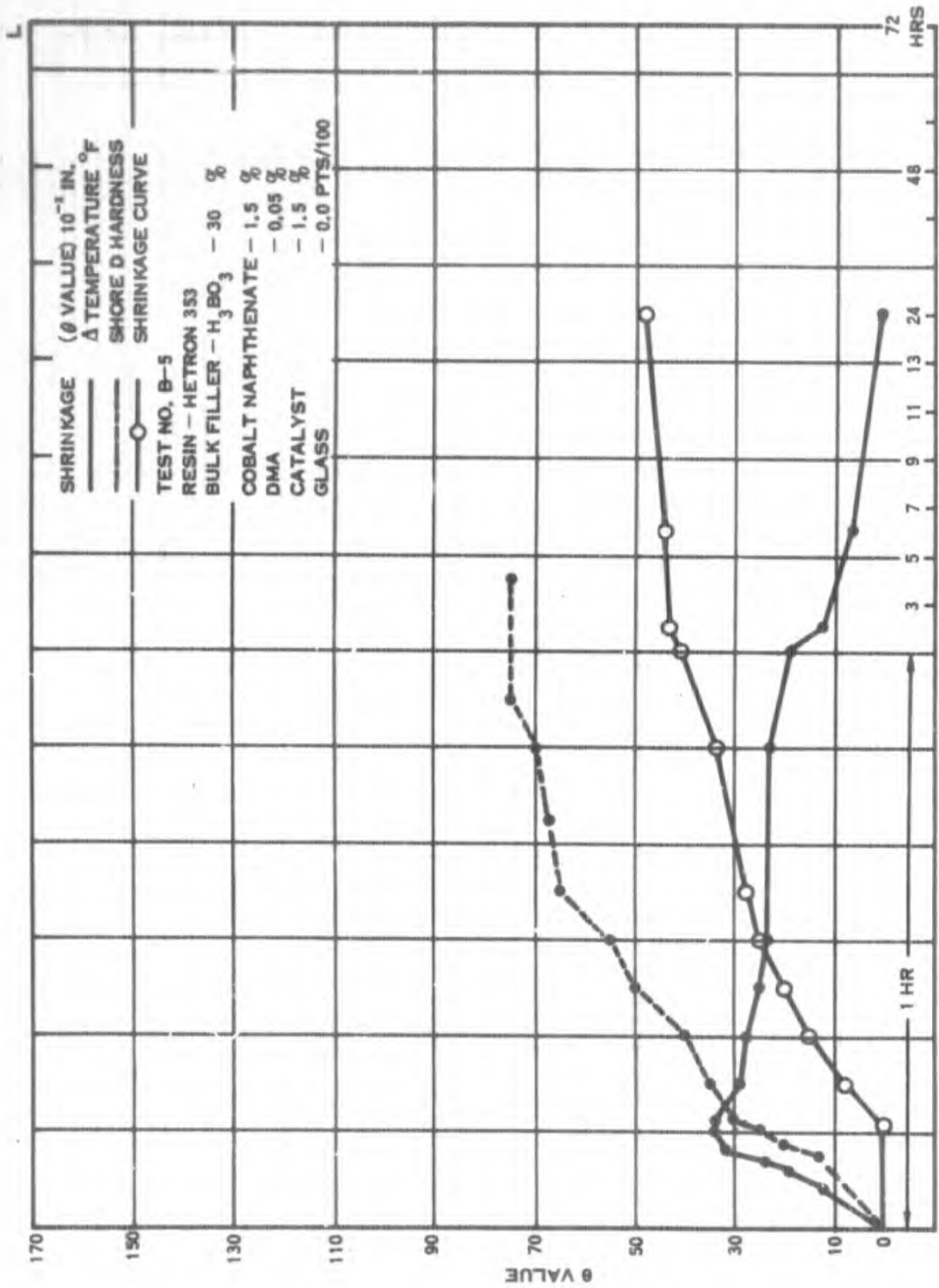


Figure 6. Shrinkage Curves (Continued) (1)

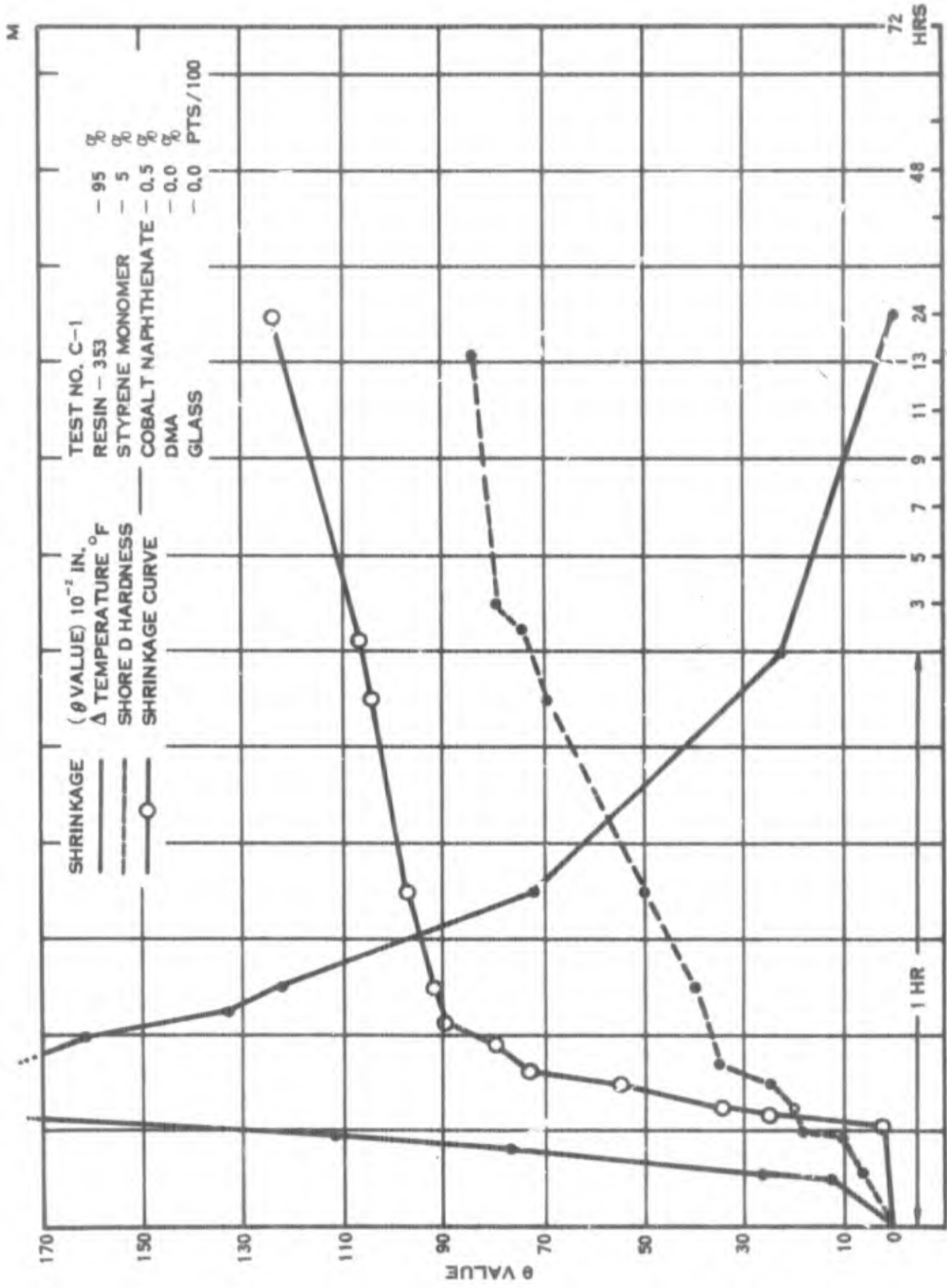


Figure 6. Shrinkage Curves (Continued) (m)

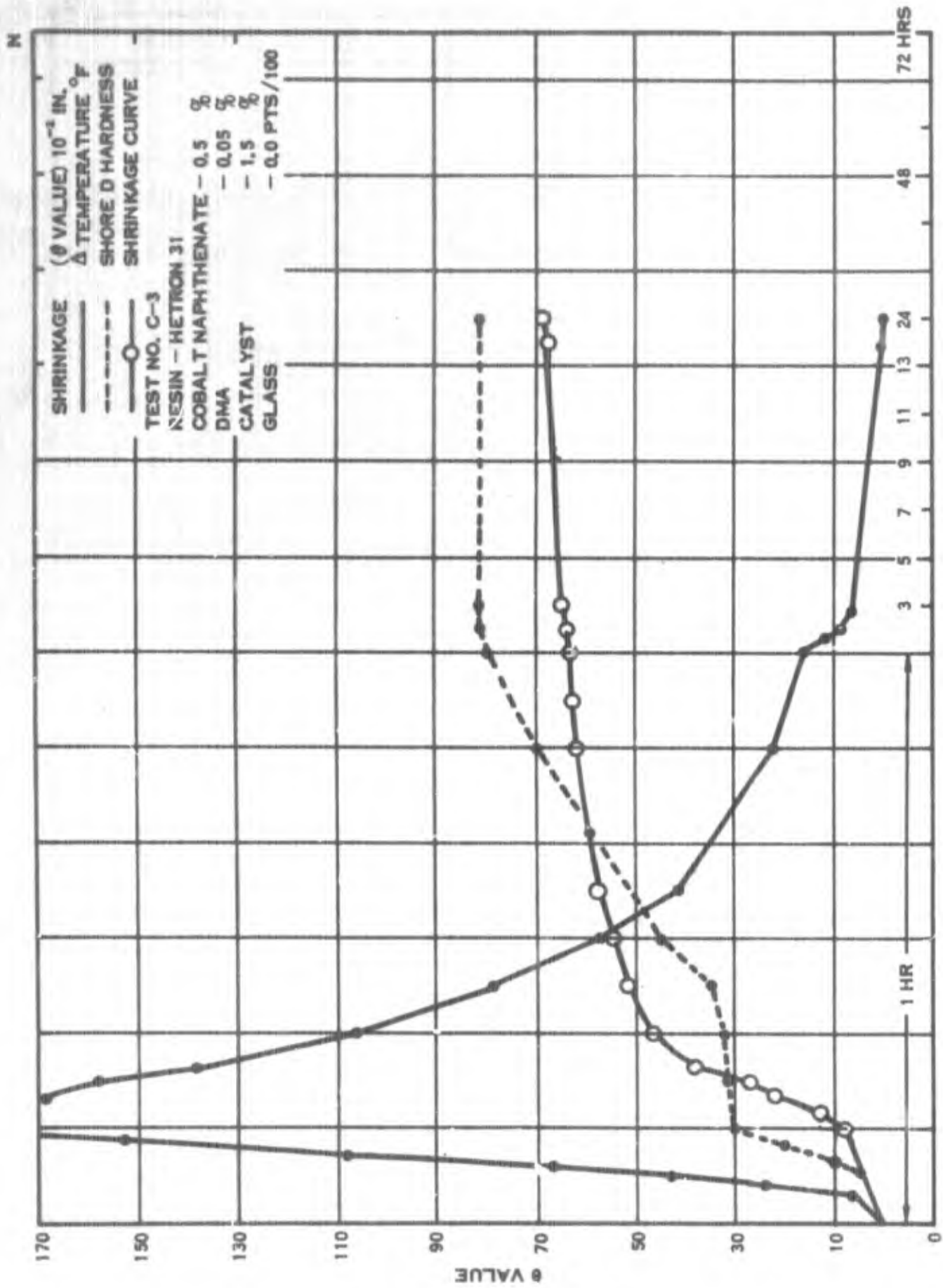


Figure 6. Shrinkage Curves (Continued) (n)

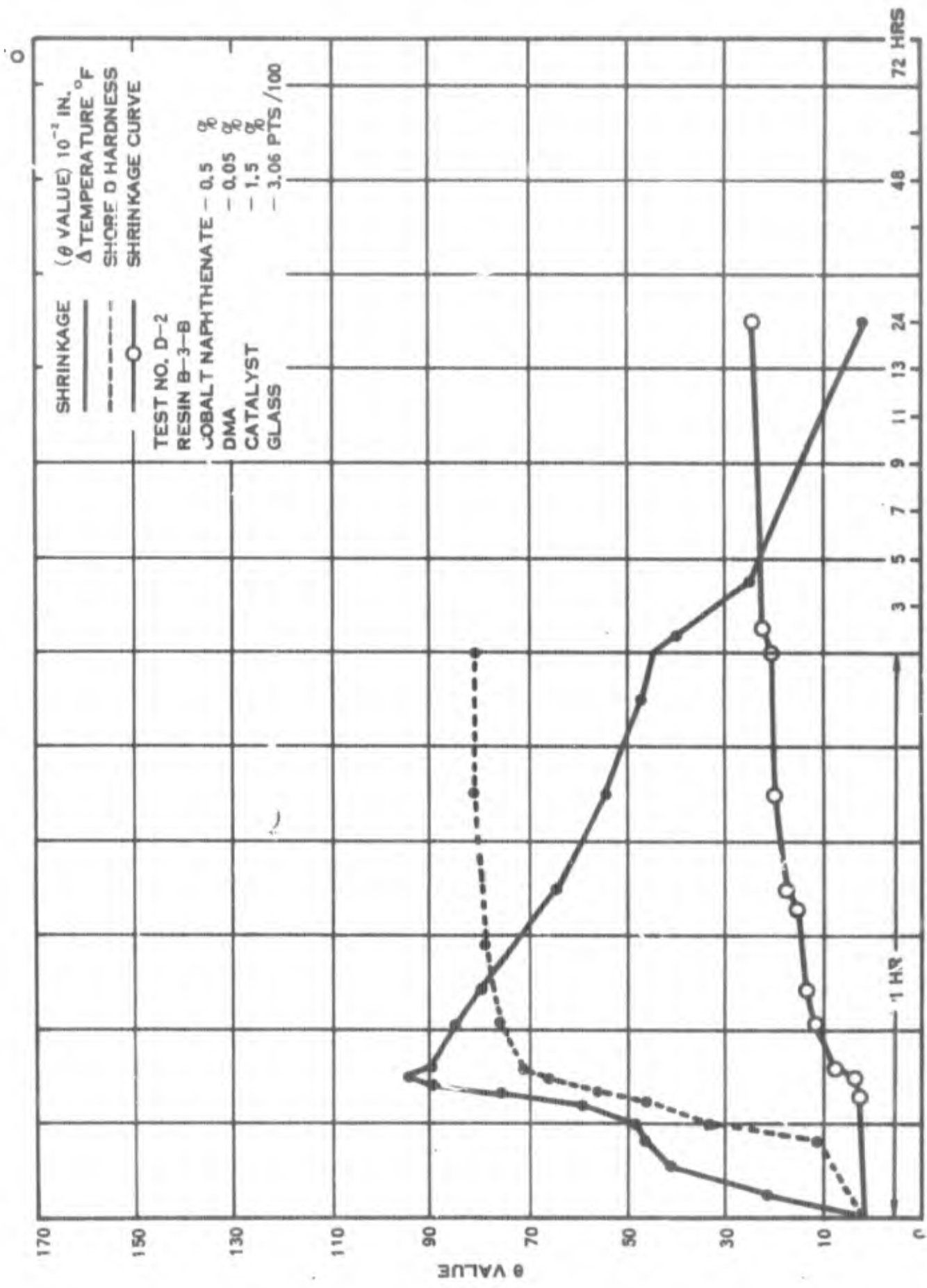


Figure 6. Shrinkage Curves (Continued) (o)

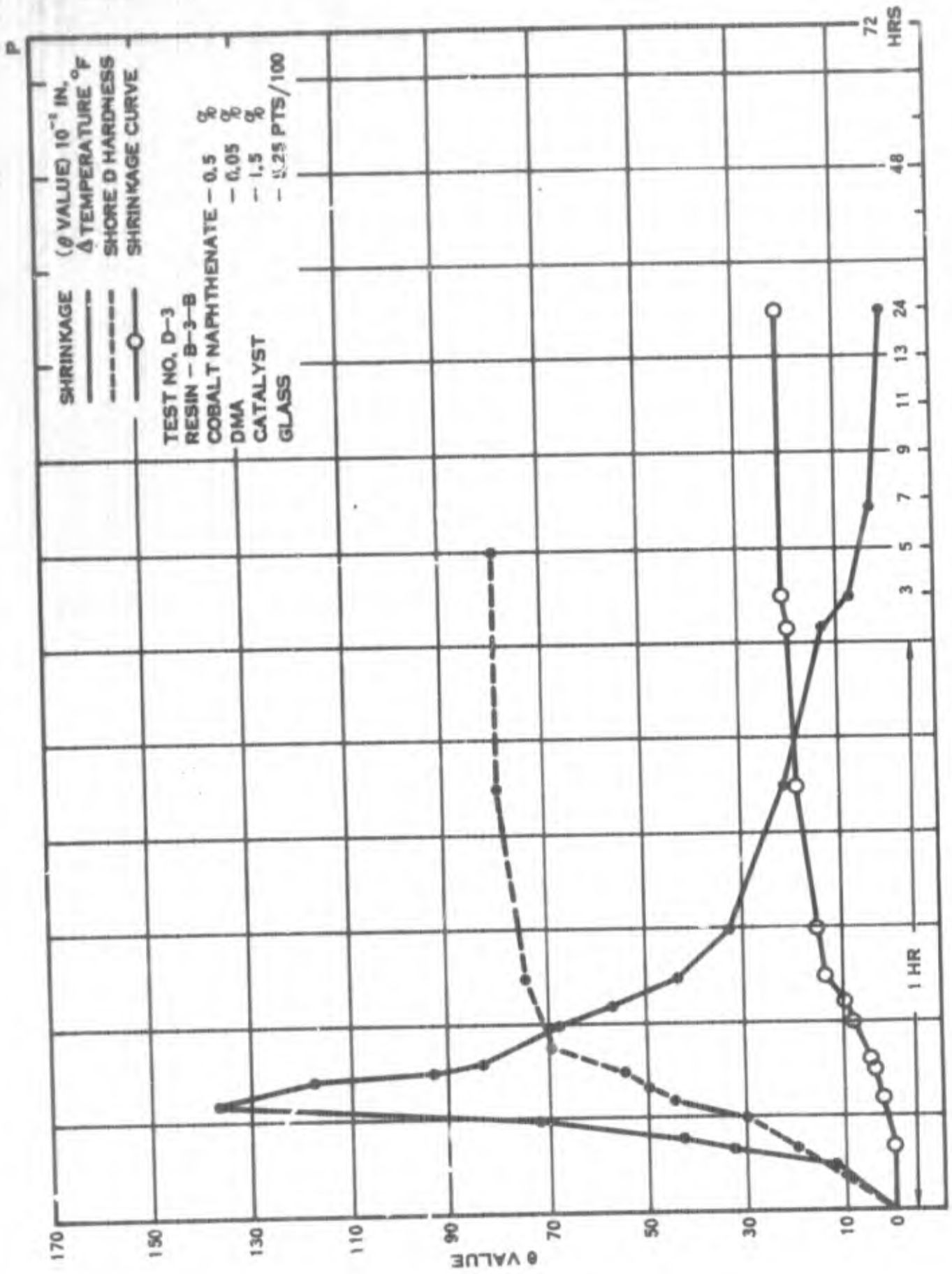


Figure 6. Shrinkage Curves (Continued) (P)

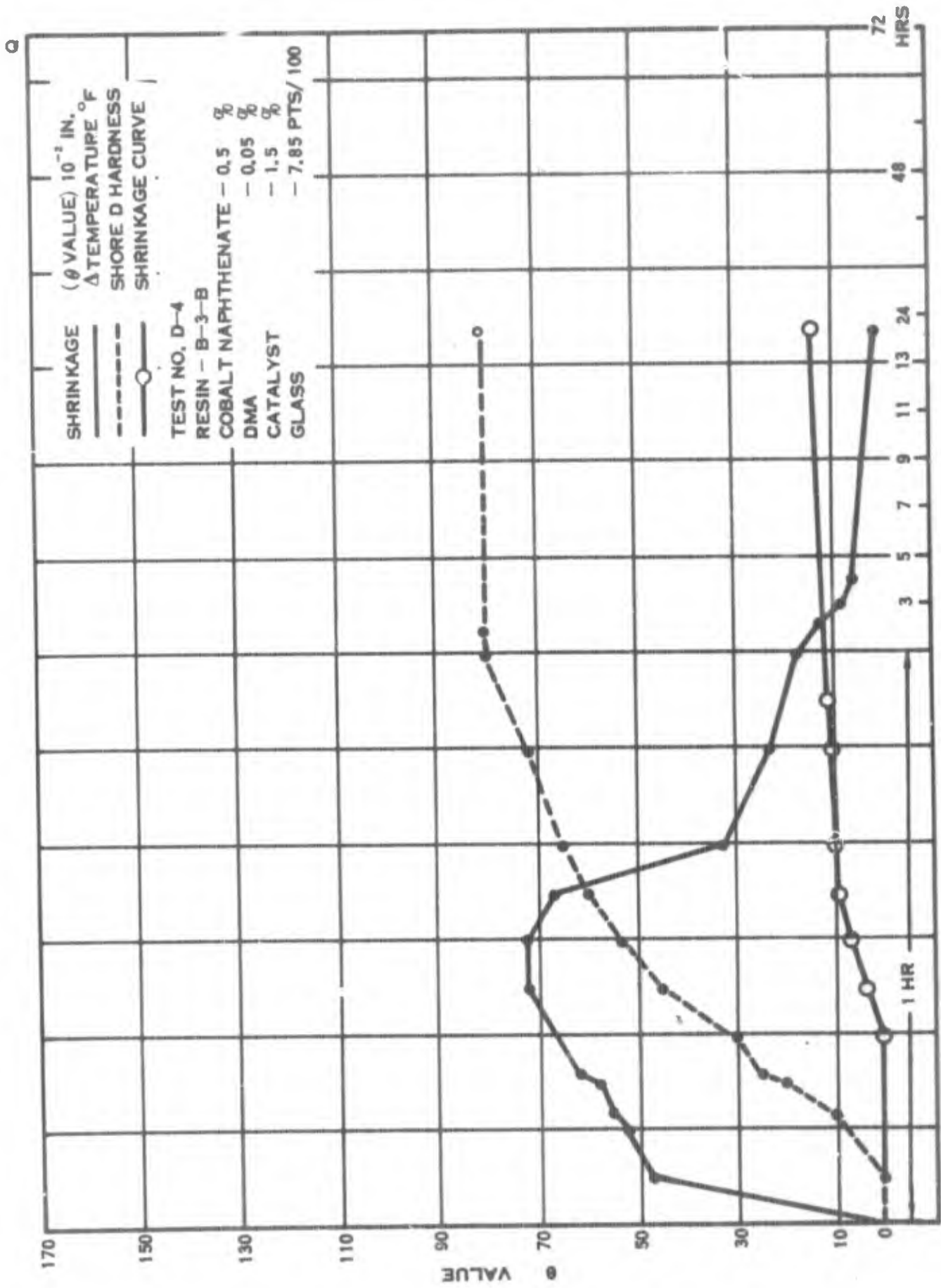


Figure 6. Shrinkage Curves (Continued) (q)

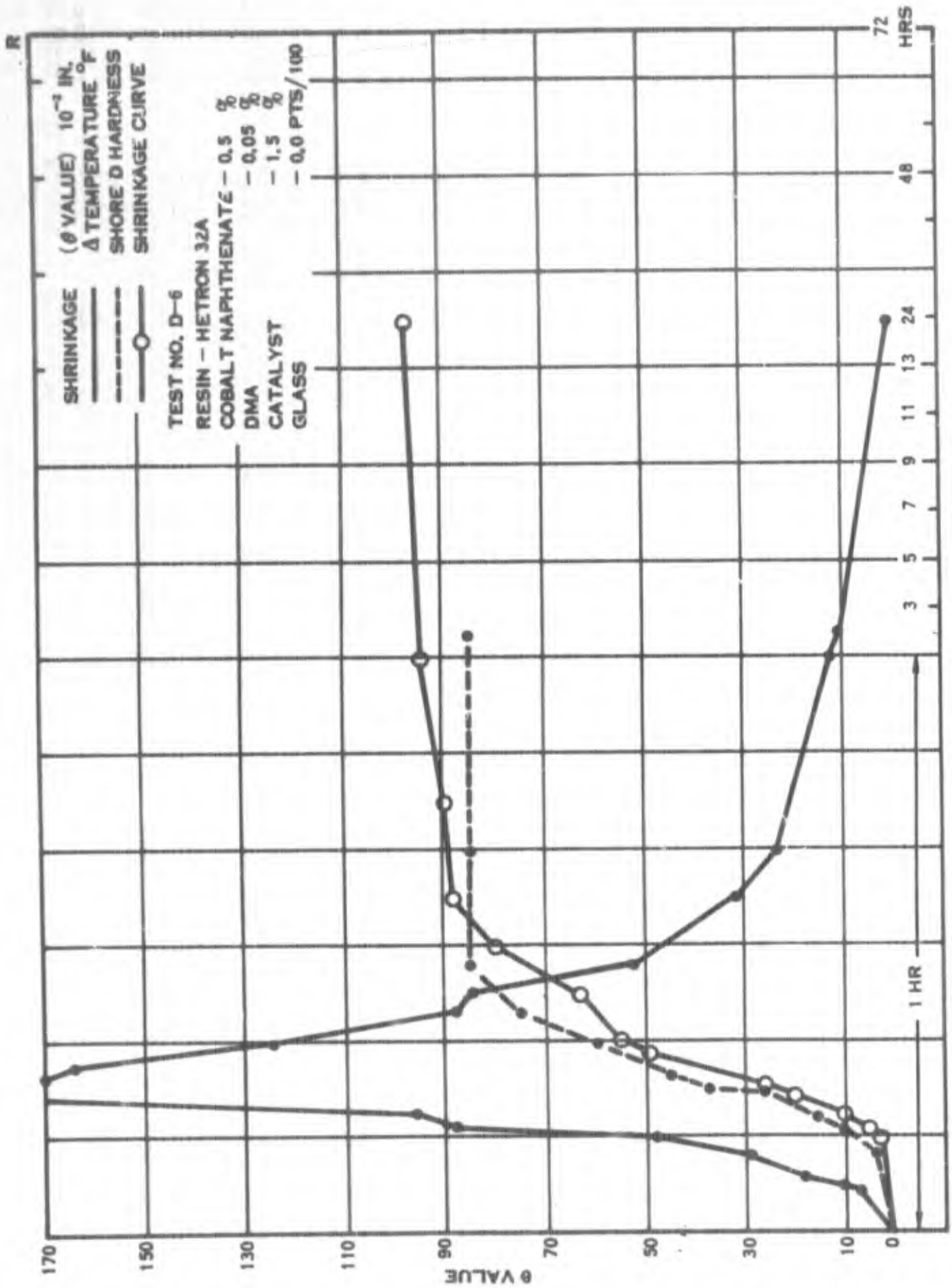


Figure 6. Shrinkage Curves (Continued) (r)

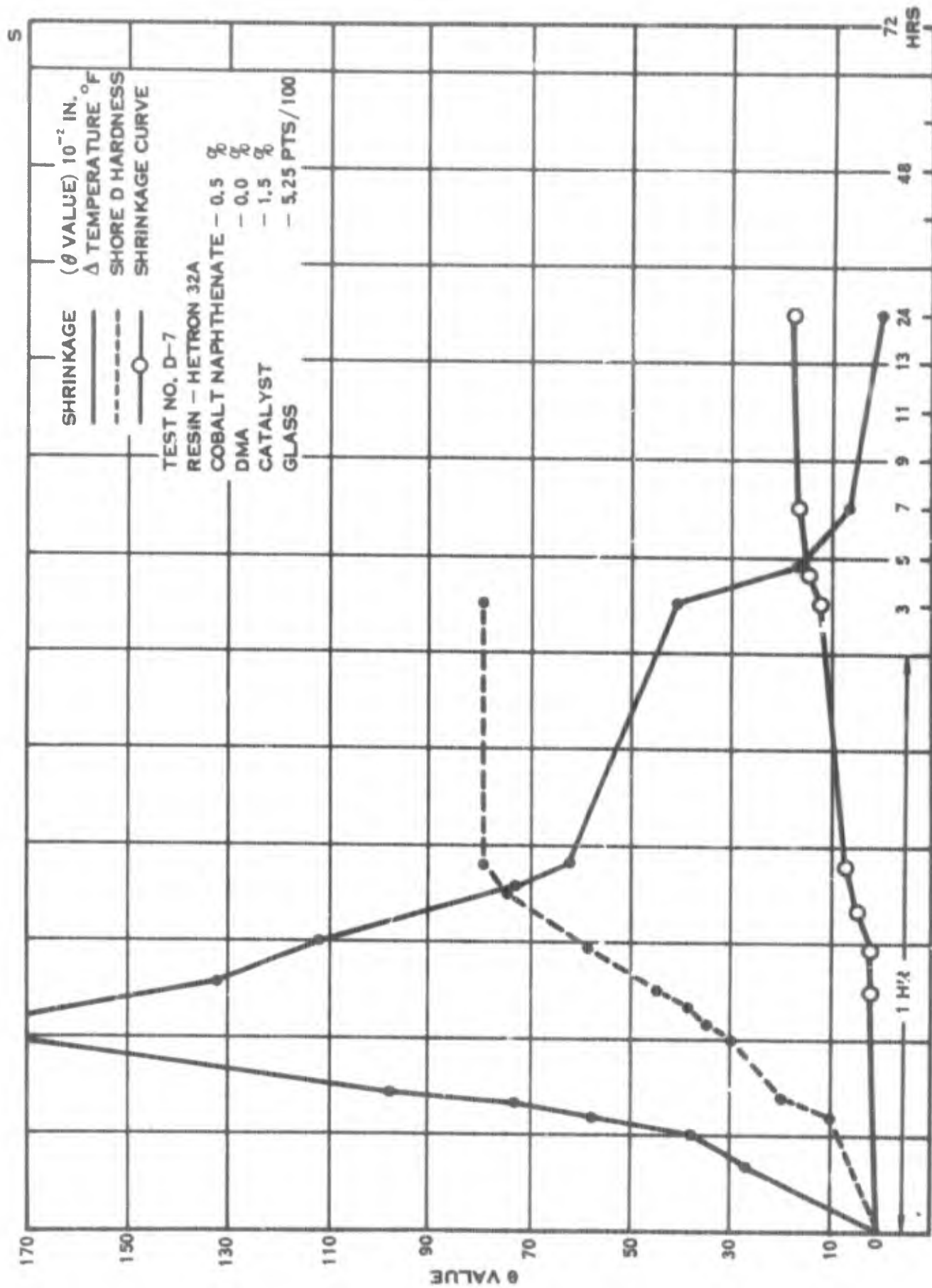


Figure 6. Shrinkage Curves (Continued) (a)

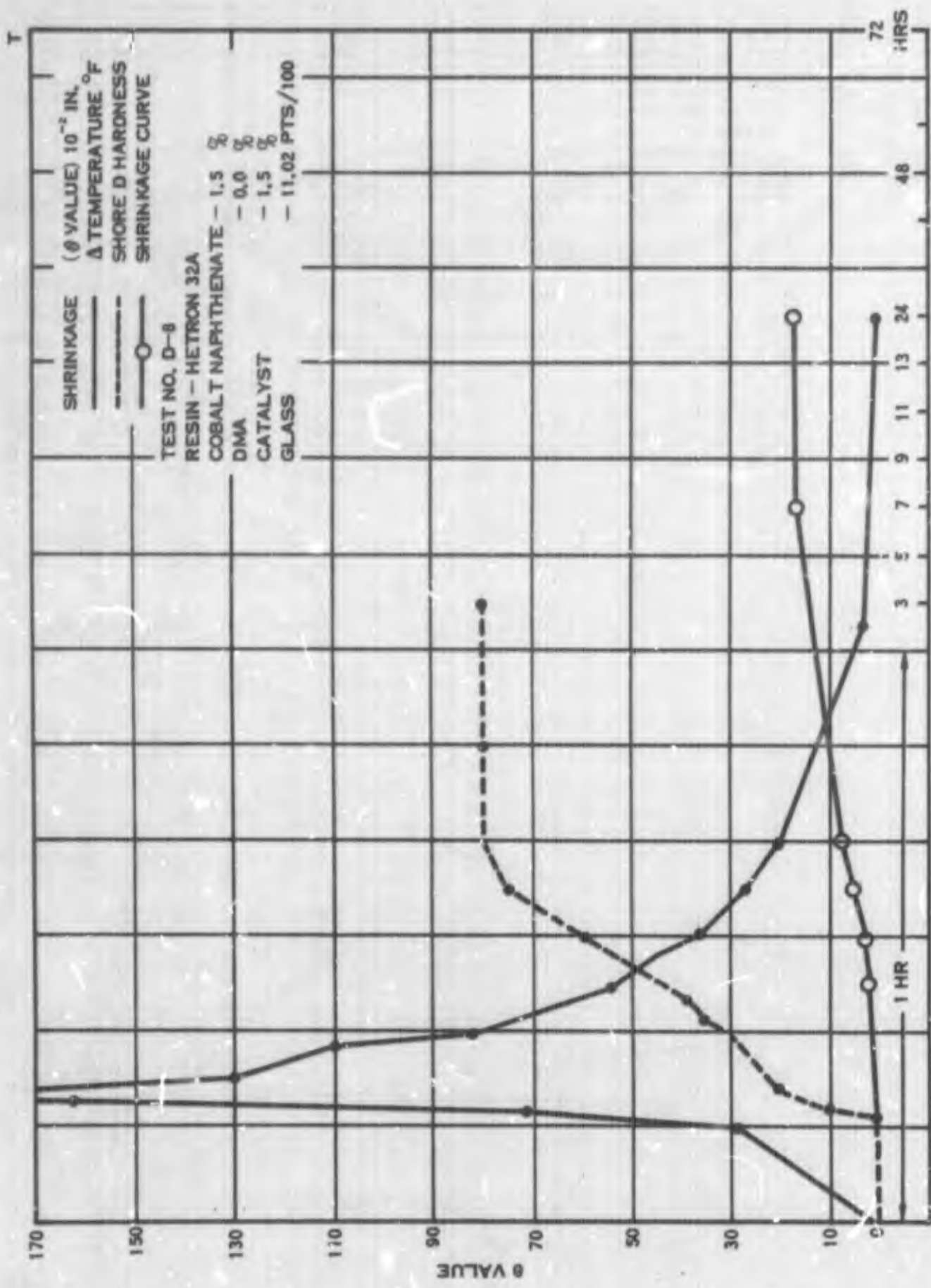


Figure 6. Shrinkage Curves (Continued) (t)

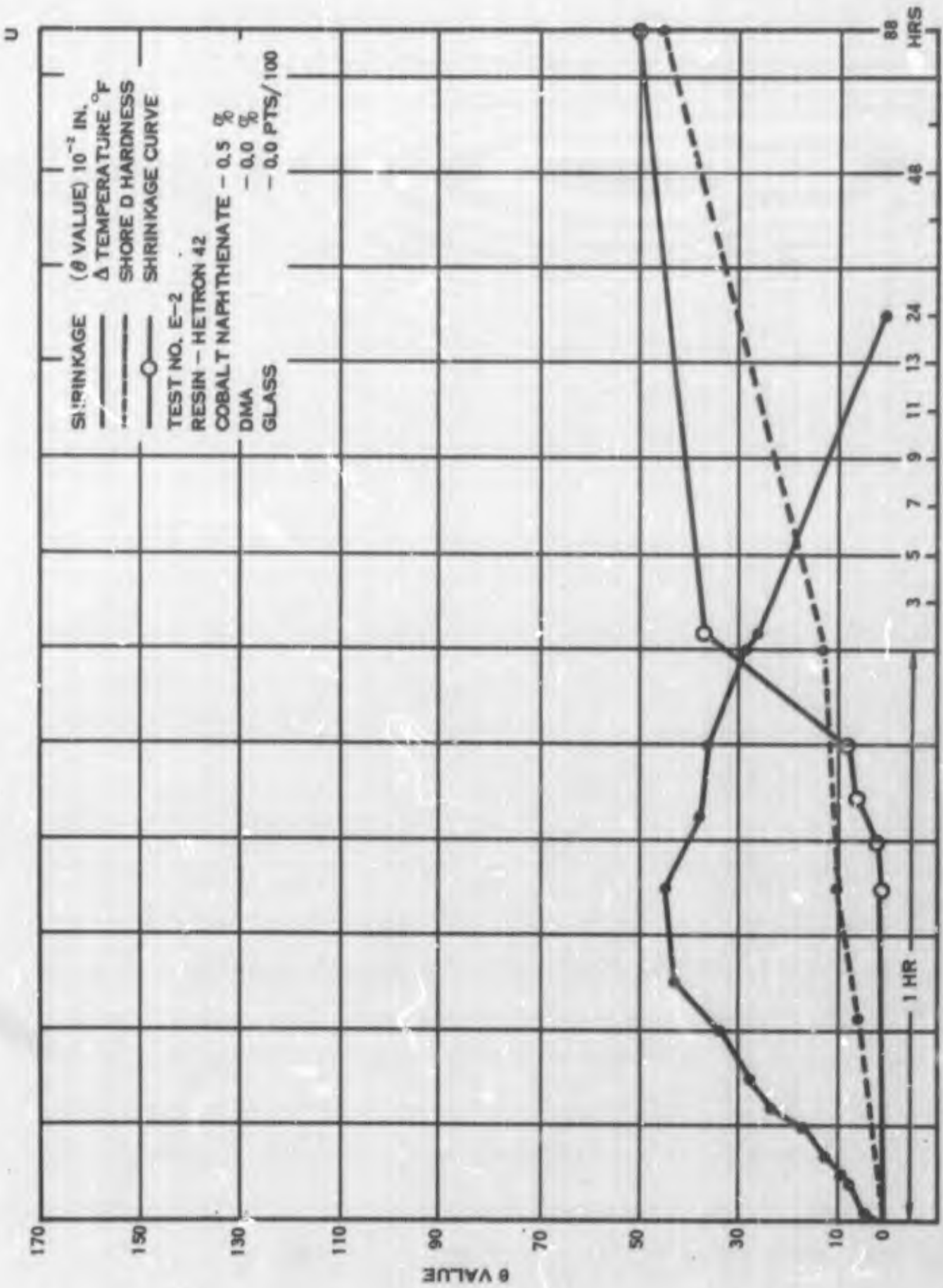


Figure 6. Shrinkage Curves (Continued) (u)

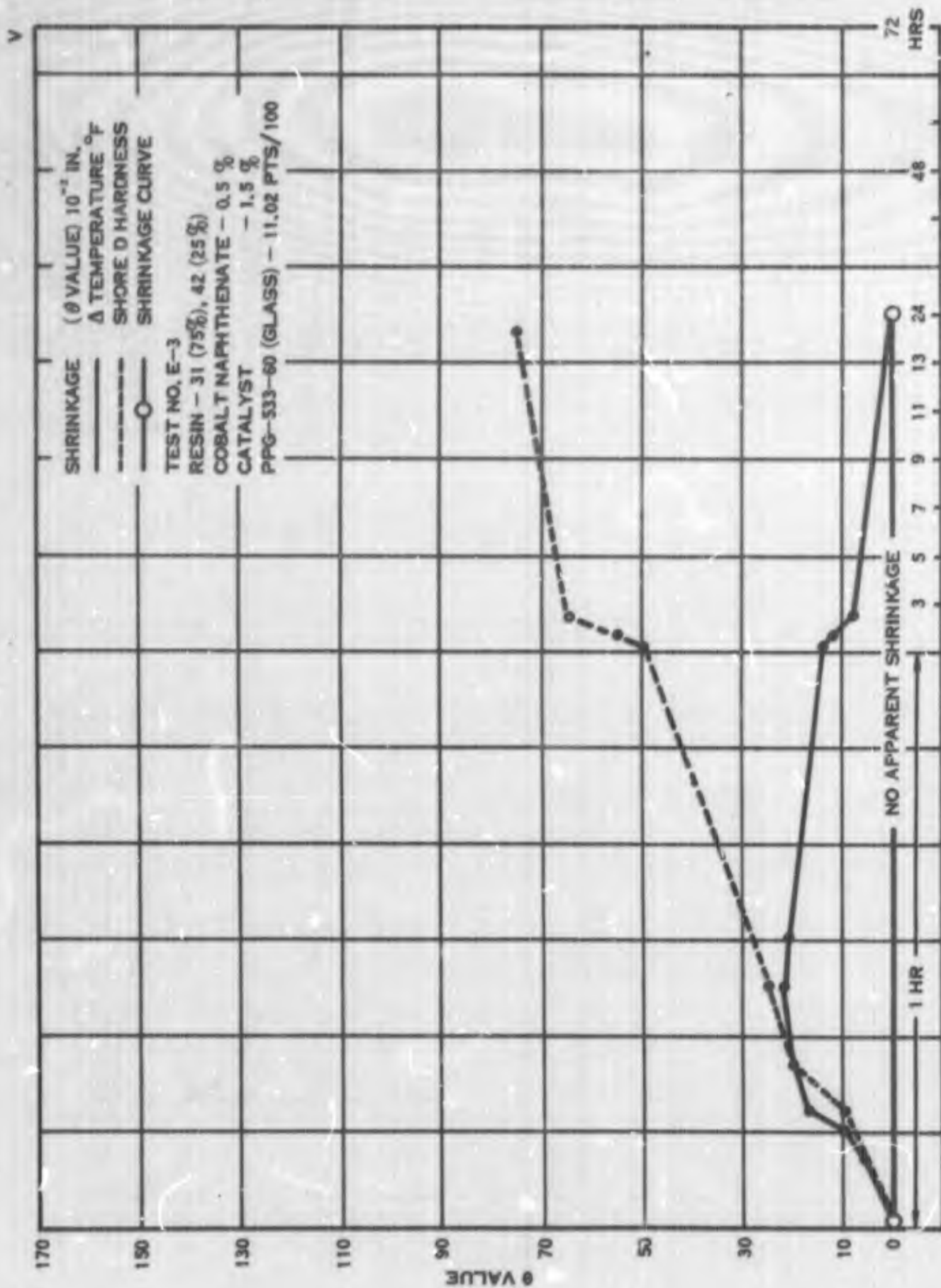


Figure 6. Shrinkage Curves (Continued) (v)

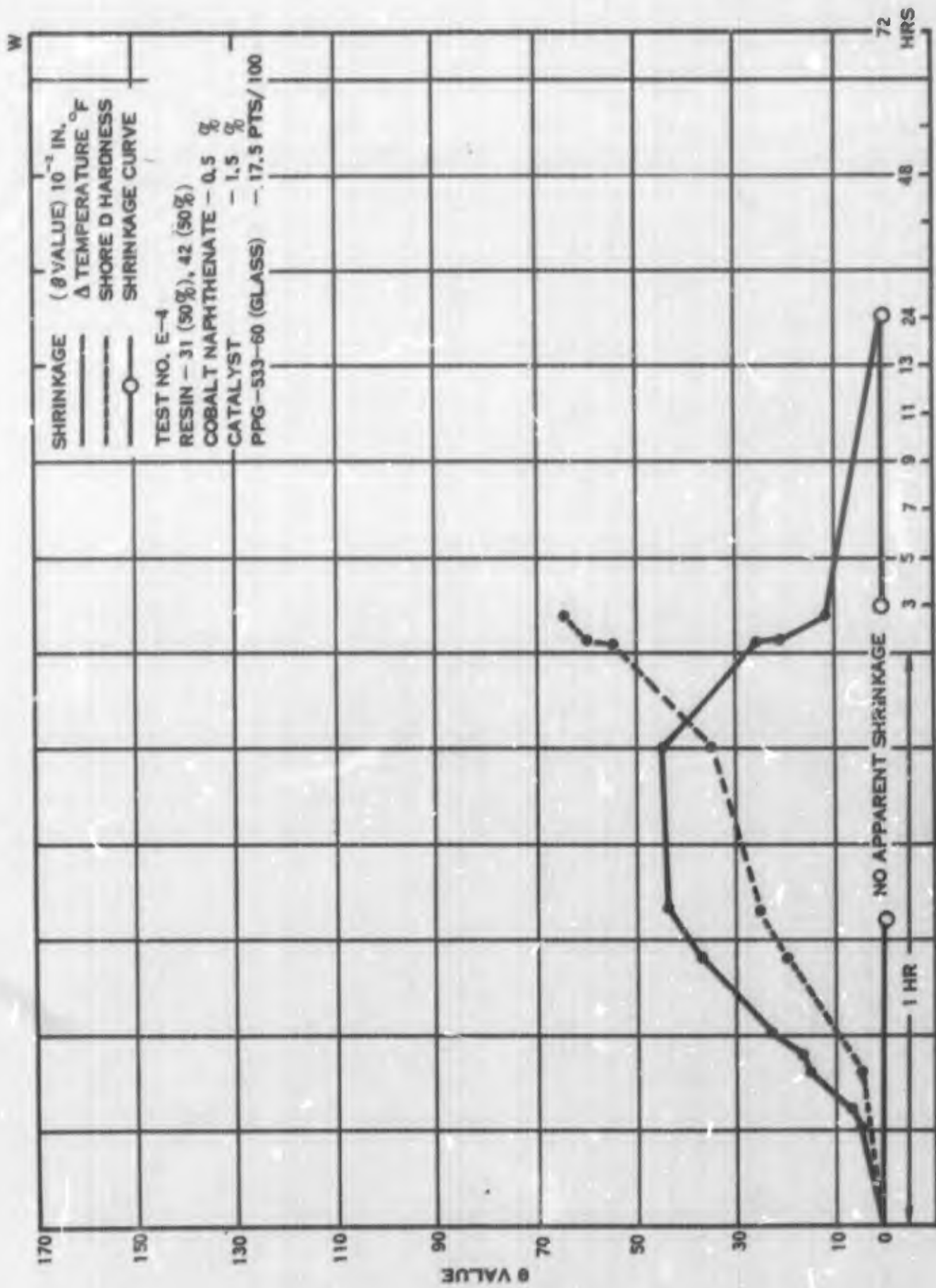


Figure 6. Shrinkage Curves (Continued) (v)

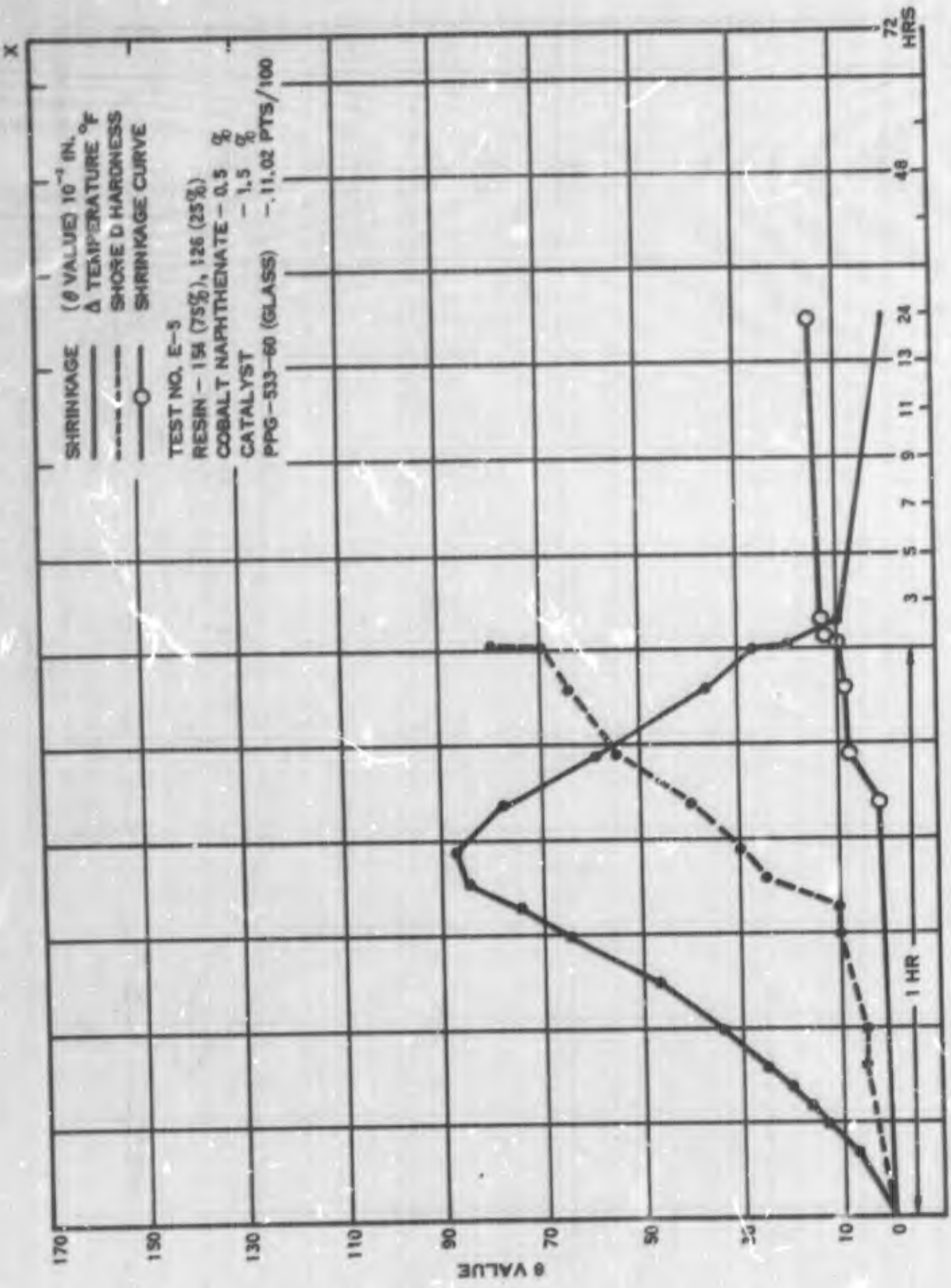


Figure 6. Shrinkage Curves (Continued) (x)

Y

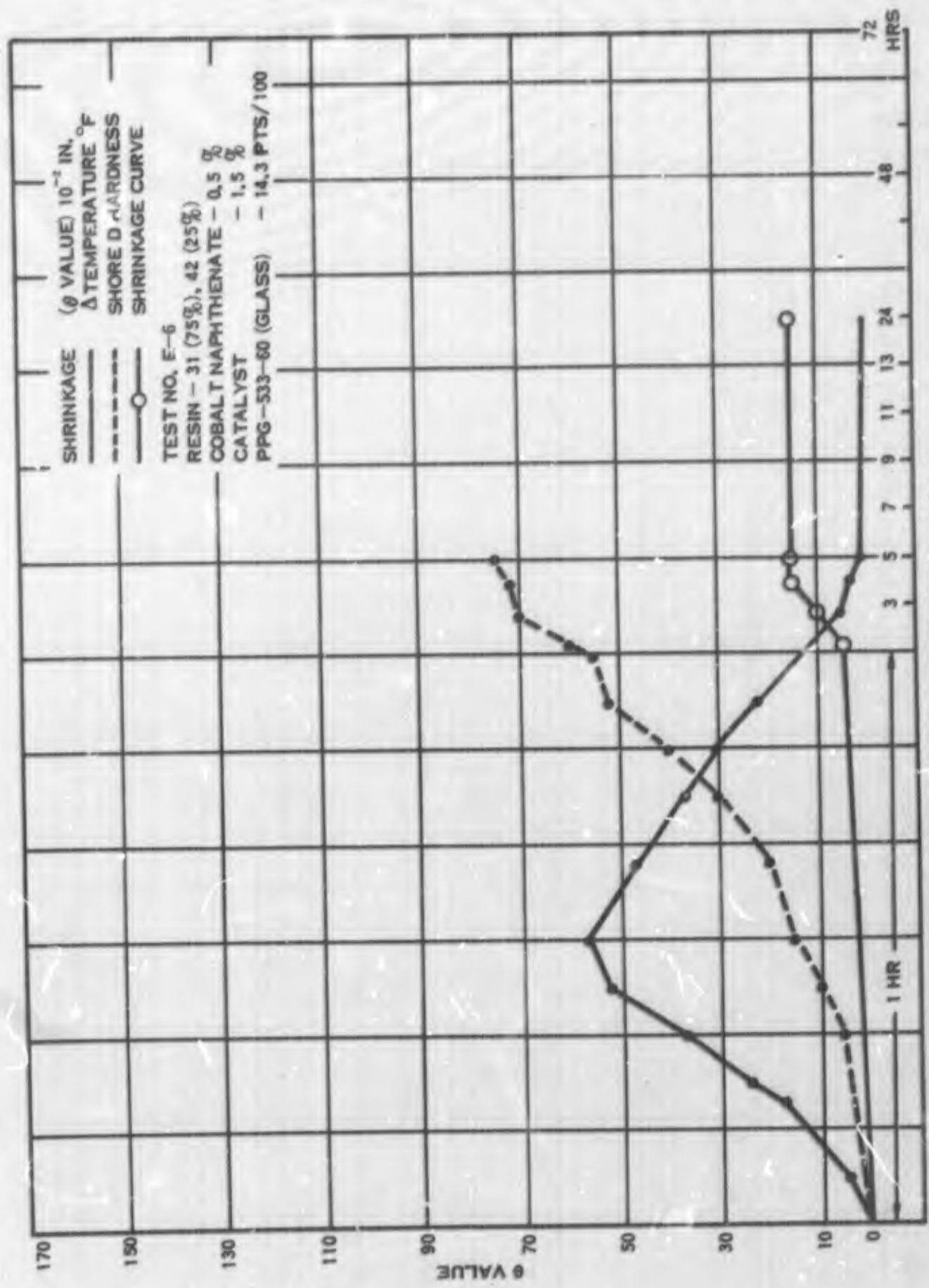


Figure 6. Shrinkage Curves (Continued) (y)

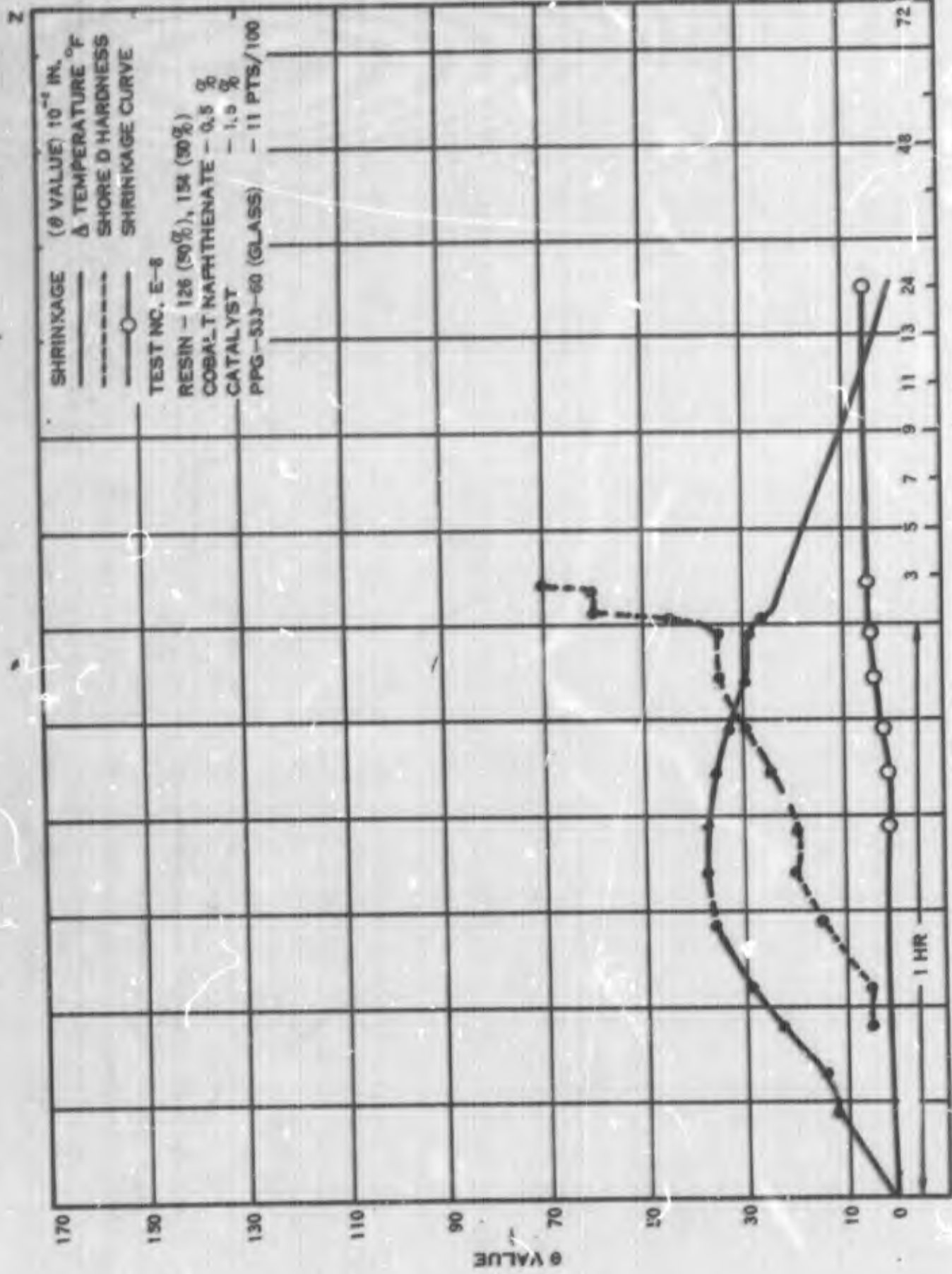


Figure 6. Shrinkage Curves (Continued) (z)

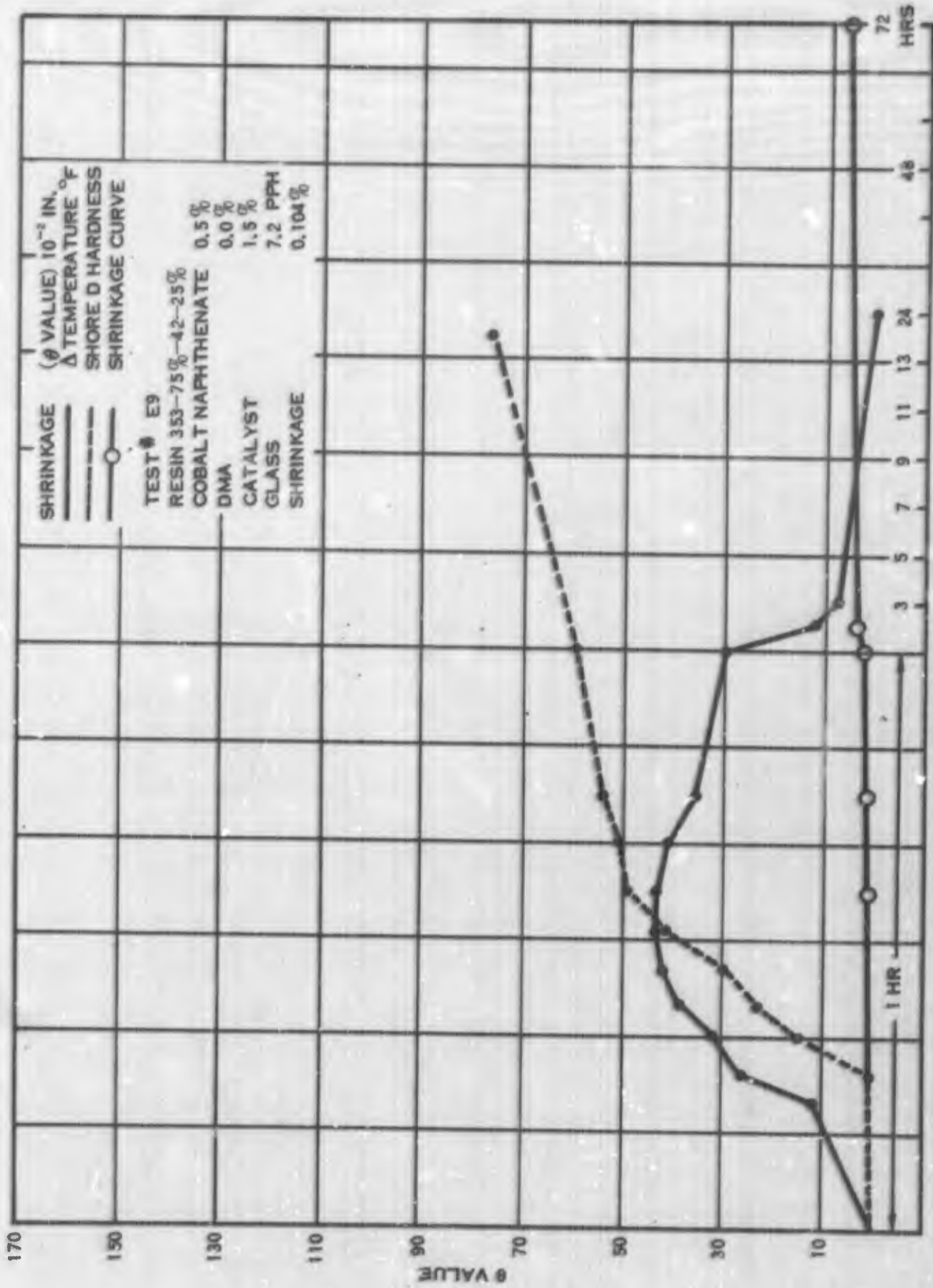


Figure 6. Shrinkage Curves (Continued) (aa)

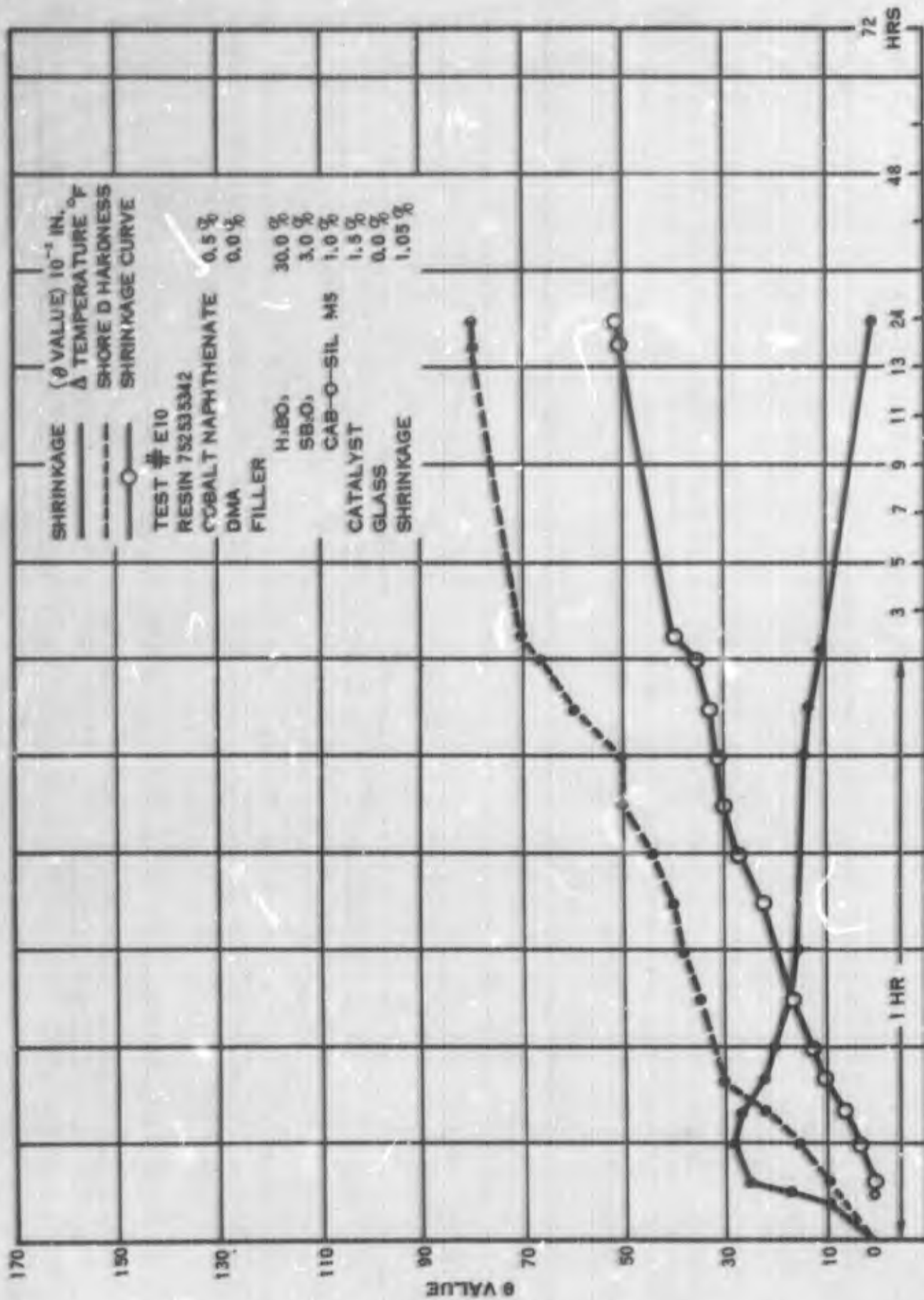


Figure 6. Shrinkage Curves (Continued) (ab)

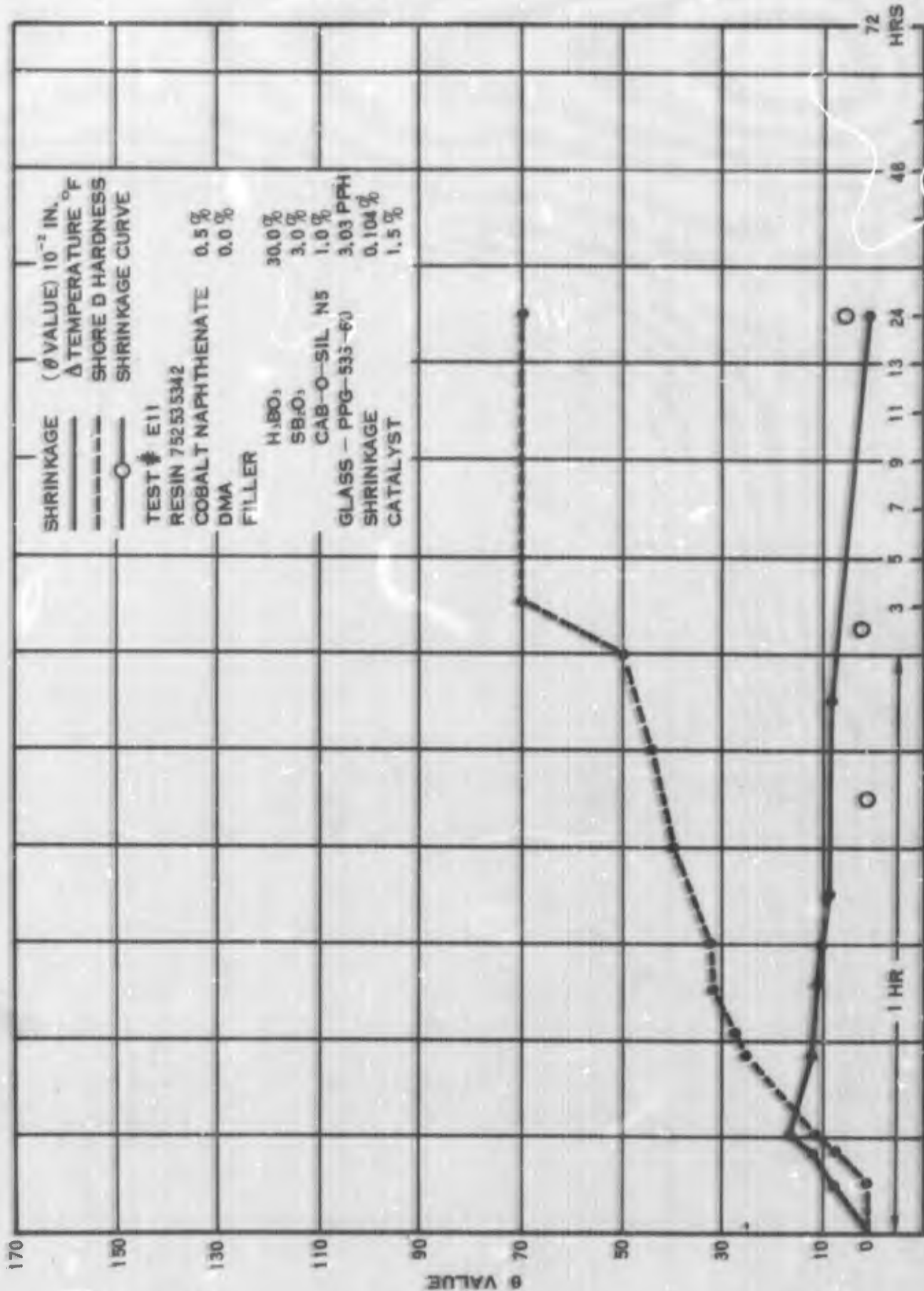


Figure 6. Shrinkage Curves (Continued) (ac)

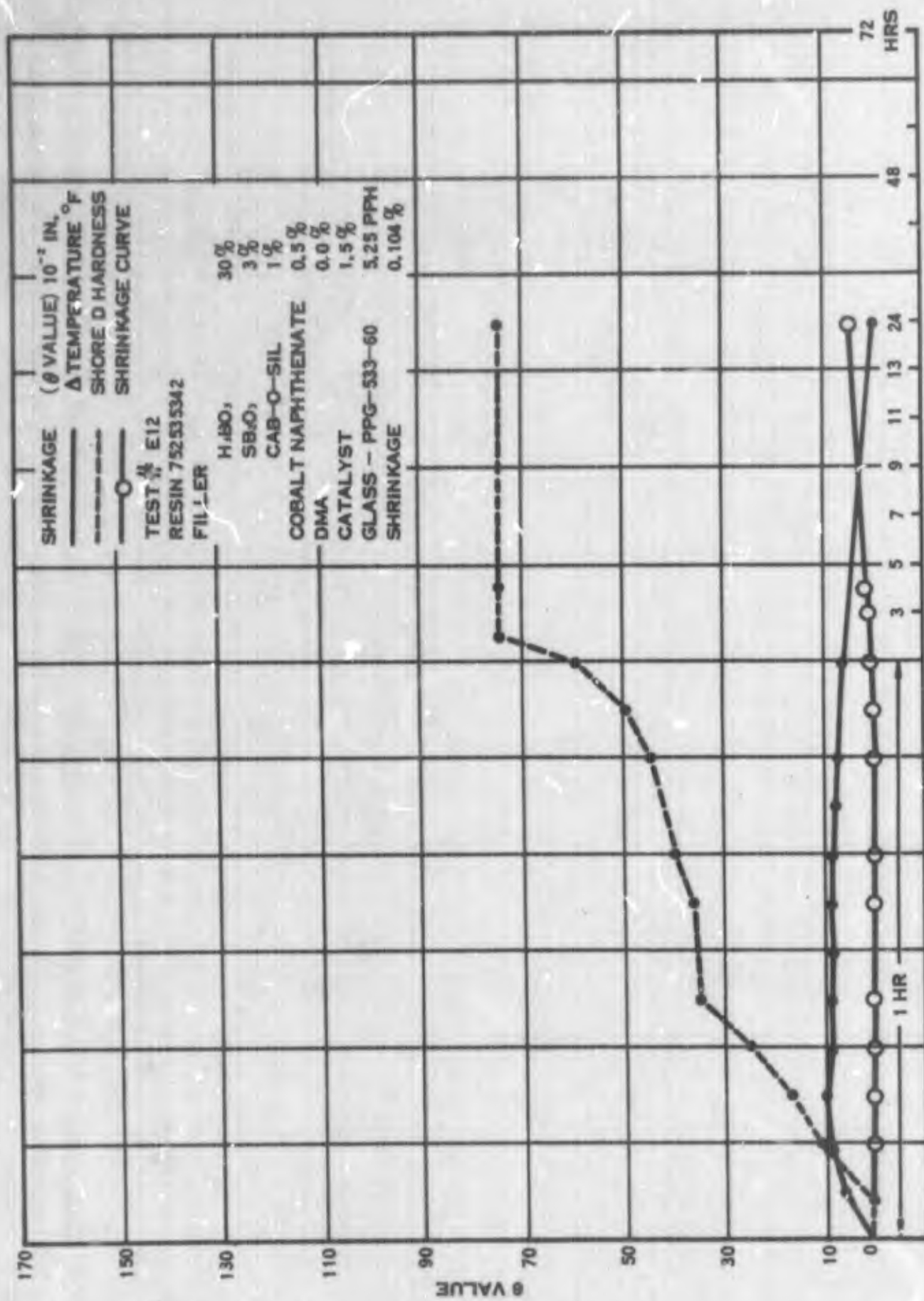


Figure 6. Shrinkage Curves (Continued) (ad)

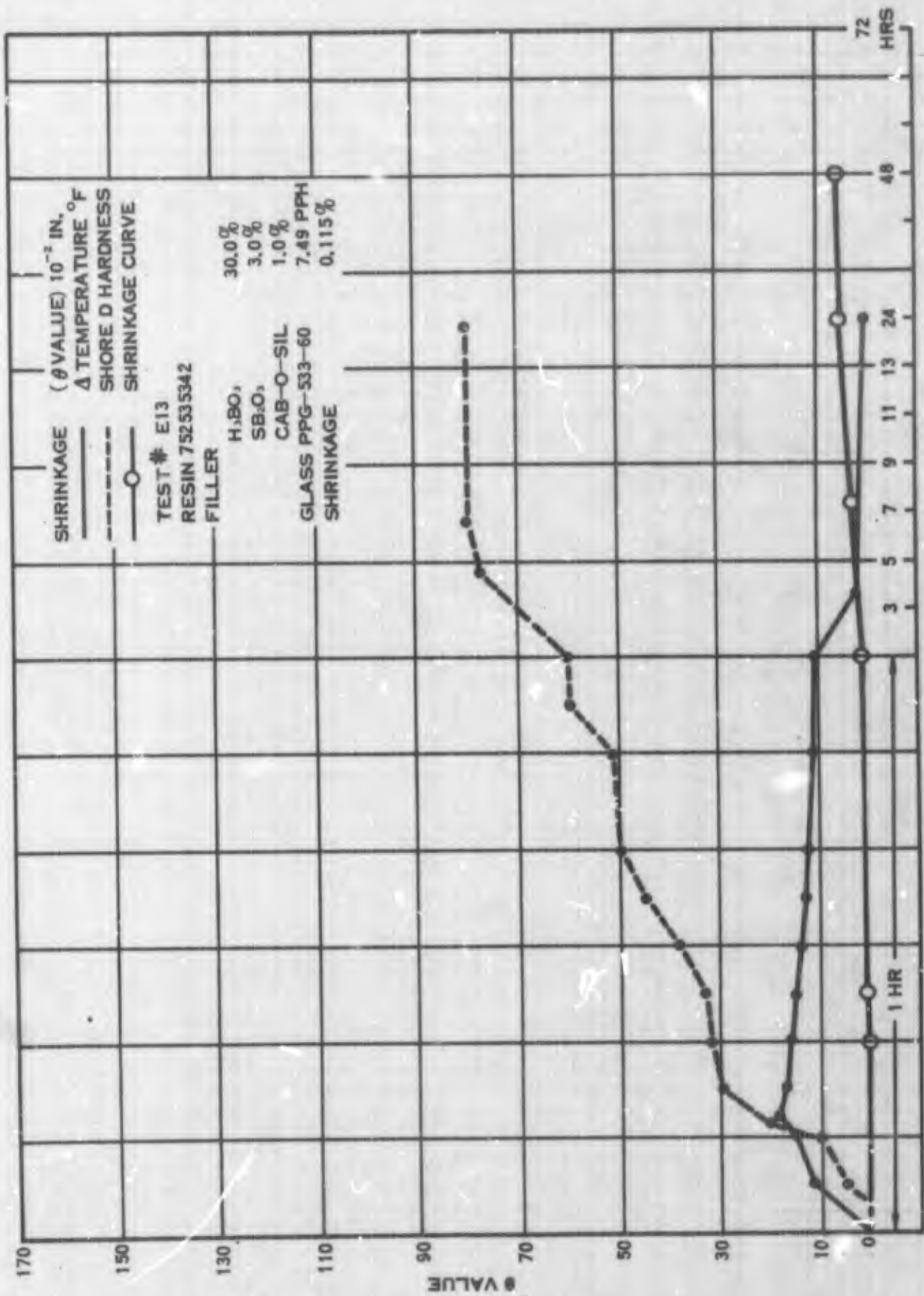


Figure 6. Shrinkage Curves (Concluded) (as)

A literature search revealed that Hetrons 32A and 31 with cast tensile strengths of 9300 and 6600 psi respectively would offer a definite improvement over Hetron 353 (cast tensile strength 3300 psi). The literature also revealed a unique material, Hetron 42, which, while low in strength, would yield 100% elongation. These materials formed the "building blocks" from which the selected formulations were made.

Utilization of the shrinkage, torch test, and AFAPL jet engine test data enabled the investigator to narrow the field of strength testing considerably. Hetron 32A, the highest strength candidate, proved to be highly reactive and produced an unexpectedly high shrinkage. Unmodified Hetron 31 produced lower shrinkage but the data indicated that modification with Hetron 42 would be beneficial.

Subsequently, a formulation consisting of 75% Hetron 31 and 25% Hetron 42 was evaluated both as a primary resin for low (non-afterburning) temperature operation and as a base resin to be compounded with ablative fillers for afterburning applications. During jet engine tests at AFAPL, however, it was ascertained that low boric acid concentrations did not produce the desired resistance to afterburning jet engine exhaust and high boric acid concentrations produced excessive viscosity. The unfilled 31/42 material, when incorporated in the reinforcement system discussed below, yielded excellent strength improvement compared with the previous reinforcement and B-3-B resin system.

Torch test and confirming jet engine exposure data indicated that boric acid concentrations on the order of 28 to 30% would be required to successfully resist afterburning environments. Incorporation of this concentration of boric acid required a lower viscosity base resin than the Hetron 31/42 mixture. A compromise resin consisting of 75% Hetron 353 and 25% Hetron 42 provided the base for additive compounding. The strength of this system is on the same order as the B-3-B resin but the new system should be somewhat more flexible. It is therefore intended that the afterburner exhaust resistant material (75/25 - 353/42 filled) be used as an overlay on the high strength material (75/25 - 31/42 unfilled).

## (2) Reinforcement Development

The overall strength of the systems under investigation is determined by both the concentration and nature of reinforcement.

One method of incorporating higher concentration of glass reinforcement is utilization of a woven roving fabric. While this reinforcement has only limited compatibility with the filled resins used exclusively in previous research, the fabric is quite adaptable to unfilled resins. The combination of the woven roving and sufficiently fluid resin produces a composite with approximately twice the strength of the previous filled resin-low reinforcement system.

It should be noted that similar concentrations of sprayed glass roving produce laboratory flexure values as high or higher than the woven roving. It should be further noted that sprayed roving specimens fractured whereas the woven roving specimens did not. The values shown for woven roving were derived from the loading at which the specimens deflected sufficiently to be extracted from the test fixture by the loading mechanism.

In actual practice, a combination of sprayed and woven roving appears to be superior to either system above. The sprayed roving tends to aid in distribution of resin over the woven roving and provides a somewhat better surface layer for resistance to turbojet engine exhaust. The woven roving provides a more uniform covering than sprayed roving. In fact, the existence of the woven roving aids in maintaining uniform distribution of the sprayed roving. Conversely, relatively unprepared sites may require tailoring of certain areas due to rocks, grass, or other obstructions. In these situations, the sprayed roving allows a greater degree of freedom to fabricate the localized area in the optimum manner required.

The major disadvantage of the woven roving is that dispensing thereof creates an additional task which could tend to increase crew requirements slightly. This is somewhat offset by the relatively high speed at which the woven roving can be dispensed and the elimination of 90% of site layout time through use of pre-marked woven roving fabric.

Table II contains Flexural Strength data for the various fiberglass and resin systems.

#### g. Post-European Field Test Sites

Five post-European field test sites (PEFTS) were fabricated during the span of Phase I to evaluate the applicability and compatibility of selected resin and reinforcement systems. The field fabrication conditions and test data are as follows:

##### (1) Post-European Field Test Site No. 1

Nozzle:	5/15 inch circular external with Food Machinery Catalyst injection tube
Resin:	75/25-31/42
Promotion:	.5% Cobalt Naphthenate; .05% DMA
Catalyst:	Lupersol DDM, 75 steel ball on Glass-Craft pot. Approximately .75 lb/min flow
Resin	
Flow Rate:	36 lb/min (estimated)

TABLE II POST EUROPE FLEXURAL DATA

MATERIAL SYSTEM	REINFORCEMENT		FLEXURAL STRENGTH (PSI)
	TYPE	% OF TOTAL	
Hetron 75/25 - 31/42	PPG-533-60 sprayed roving on top 24 oz/yd <sup>2</sup> woven roving on bottom	2.6	12,330*
		11.3	20,650*
		2.9	13,720*
		10.7	18,430*
		3.4	11,710*
		10.6	20,650*
		2.6	15,000
		11.2	20,400
		2.5	23,700
		10.6	25,100
		2.4	11,600*
		11.5	
		3.0	
		5.0	
10.1			
15.0			
Hetron 50/50 - 31/42	PPG-533-60 sprayed roving	3.0	11,600*

TABLE II POST EUROPE FLEXURAL DATA (Continued)

MATERIAL SYSTEM	REINFORCEMENT		FLEXURAL STRENGTH (PSI)
	TYPE	% OF TOTAL	
Hetron 50/50 - 31/42	PFQ-533-60 sprayed	5.0	10,000*
		10.0	11,800*
		15.0	12,200*
		20.0	16,000*
Hetron 75/25 - 353/42 H3B03 - 30.0% Sb203 - 3.0% Cab-0-S11 (M-5) 1.0%	PFQ-533-60 sprayed roving	8.0	9,520 Average for 11 specimens tested
Hetron 75/25 - 353/42 H3B03 - 30.0% Sb203 - 3.0% Cab-0-S11 (M-5) 1.0%	PFQ-533-60 sprayed roving on top 24 oz/yd <sup>2</sup> woven roving on bottom	5.2	16,940
		5.3	Average for 11 specimen's tested
Hetron 90/10 - 353/42 H3B03 - 30.0% Sb203 - 3.0% Cab-0-S11 (M-5) 1.0%	PFQ-533-60 sprayed roving	8.0	11,600
Hetron 90/10 - 353/42 H3B03 - 30.0% Sb203 - 3.0% Cab-0-S11 (M-5) 1.0%	PFQ-533-60 sprayed roving on top 24 oz/yd <sup>2</sup> woven roving on bottom	5.2	14,900
		5.3	Average for 6 specimens tested

TABLE II POST EUROPE FLEXURAL DATA (Continued)

MATERIAL SYSTEM	REINFORCEMENT		FLEXURAL STRENGTH (PSI)
	TYPE	% OF TOTAL	
B-3-B Formula (Control)	PPG-533-60 sprayed roving on top 24 oz/yd <sup>2</sup> woven roving on bottom	5.3  5.3	17,780  Average for 8 specimens tested
Hetron 75/25 - 31/42  Hetron 75/25 - 353/42 H3B03 - 30.0% Sb203 - 3.0% Cab-0-S11 (M-5) 1.0%	24 oz yd <sup>2</sup> roving (1st layer) 24 oz/1d <sup>2</sup> woven roving (2nd layer)	12.5 (% of Layer 1) 12.5 (% of layer 2)	17,360  Average for 8 specimens tested
Hetron 24505	PPG-533-60 sprayer roving (3rd layer)  24 oz/yd <sup>2</sup> woven roving (2 layers)	5.0 (% of Layer 3)  16.0 (% of 2 layers)	26,180
Hetron 72/25 - 353/42 H3B03 - 30.0% Sb203 - 3.0% Cab-0-S11 (M-5) 1.0%	PPG-533-60 sprayed roving (3rd layer)	7.0 (% of 3rd layer)	Average for 7 specimens tested

\*No breakout. Specimen slipped out of machine.

**Ambient**

**Conditions:** Snow falling, 32-30°F, strong wind from behind sprayers

**Pad Density:** 4 lb/ft<sup>2</sup>

**Procedure:** A 10 x 10-foot pad was constructed with PPG-533-60 sprayed roving and approximately 300 pounds of resin. The pad was rather slow curing and had not cured two hours after spraying. After approximately 64 hours, a Shore D hardness reading was taken and showed to be 55-80. There appeared to be some uncured resin underneath the pad in various spots, but all exposed surfaces had cured.

**(2) Post-European Field Test Site No. 2**

**Nozzle:** 3/8 inch circular external with long tapered peripheral internal

**Resin:** 75/25-31/42

**Promotion:** .5% Cobalt Naphthenate; .05% DMA

**Catalyst:** Lupersol DDM, 75 steel ball on Glass-Craft  
Approximately .75 lb/min flow.

**Ambient**

**Conditions:** Fair, 60°F, slight breeze from behind sprayers

**Procedure:** A field test pad was fabricated using the above mentioned resin. The pad was reinforced with 24 oz/yd<sup>2</sup> woven roving glass. The technique employed was to thoroughly spray one 3 x 4-foot sheet of woven roving with resin, then half covering this with another sheet of the same size. The second sheet was then thoroughly sprayed. This resulted in a completed pad that had a 3-foot x 2-foot center section of approximately 2.0 lb/ft<sup>2</sup> and a 2.0-foot x 3-foot section on either end that was approximately 1.0 lb/ft<sup>2</sup> density. The lap joint in the center section appeared to be very well bonded. Also, the entire pad was bonded to the ground quite securely. Since the 75/25 resin system is one of slow cure, this pad required approximately 2.5 hours cure time.

(3) Post-European Field Test No. 3

Nozzle: 3/8 inch circular external with long tapered peripheral internal

Resin: 75/25-31/42

Promotion: .5% Cobalt Naphthenate; .05% DMA

Catalyst: Lupersol DDM, 75 steel ball on Glass-Craft pot. Approximately .75 lb/min flow

Resin  
Flow Rate: 36 lb/min (estimated)

Ambient  
Conditions: Fair, 72°F, slight breeze from behind  
sprayers

Procedure: An 8-foot x 50-inch strip of 24 oz/yd<sup>2</sup> woven roving was placed on the ground. The roving was sprayed with approximately 27 pounds of resin. A second layer of roving was placed slightly over half of the first. This was in turn sprayed with resin. A third strip was added as above. A time period of approximately 45 seconds was required for spraying each layer. An attempt was made to incorporate sprayed roving into areas containing excess resin. This attempt was unsuccessful due, in part, to a rapid cure (5 minutes).

(4) Post-European Field Test No. 4

The nozzle, resin, promotion, catalyst flow rate, and ambient conditions were identical to PEFT No. 3, except that the breeze was at a right angle to the linear fabrication dimension.

Procedure: An initial layer of sprayed roving was applied. A layer of woven roving was applied over the sprayed material. The woven roving was wetted thoroughly with resin and over-sprayed with spray roving. Two additional layers were added as before, yielding an 8-foot wide site with a 2 lb/ft<sup>2</sup> 4-foot wide center section and 1 lb/ft<sup>2</sup> edges.

(5) Post-European Field Test No. 5

All conditions identical with PEFT No. 3

Procedure: One layer of woven roving was applied to the terrain. A flash of resin was sprayed on the outside edge to facilitate "sticking" of the sprayed glass roving. Thereafter, the sprayed roving and resin were applied simultaneously to form a 1 lb/ft<sup>2</sup> layer. Two additional shingle layers were applied as in PEFT No. 3 and No. 4. This site had excellent quality and this procedure was used to fabricate the No. 1 Post-European Wheel Load Site (PEWLS 1). This procedure was also utilized to fabricate the 120-foot diameter helicopter landing site on Contract AF33(615)-3631.

h. Post-European Thermal Erosion Resistance Studies

The European trials indicated that the thermal-erosion resistance of the B-3-B formulation was adequate for the P.1127 and VJ101-X2 aircraft. However, factors such as excessive shrinkage and marginal strength characteristics indicated the need for modification of the material system.

The oxyacetylene torch test developed in previous investigations was utilized as a screening device. The severity of this test was maintained at the previous level although it was recognized that systems containing low or no high temperature additives would probably not complete 10 cycles. The relative number of cycles was used as an index of thermal erosion resistance.

A parametric study was made employing Hetron 31/42 (24505) and Hetron 353/42 as base resins. Both systems contained 3% antimony oxide ( $Sb_2O_3$ ) and 0.5% Cab-O-Sil M-5 as basic additives. The boric acid ( $H_3BO_3$ ) was varied from 0 to 35%. This study indicated that boric acid concentration on the order of 28 to 30% would be required to produce torch resistance on the order of that obtained with previous formulations. As it is not practical to compound this level of filler in unmodified 31/42, the investigation reverted to 353/42 as the basic resin. Subsequent (Phase II) investigation may produce a higher strength material based on monomer modified 31/42, but the eminence of full scale tests early in Phase II prompted the utilization of a material system which had somewhat more predictable properties. In addition, the 353/42 based system is primarily a modification of formulation B-3-B and is similar in all properties except shrinkage.

Torch tests on materials intended for utilization in non-afterburning applications merely indicate a reasonable probability of successful passage of AFAPL jet engine tests.

The AFAPL J85-GE5 engine provided three levels of exhaust impingement severity. The first level was a power flux density equivalent to that produced by the P.1127 aircraft. Calculated temperatures at this power level appear to be somewhat higher than the site temperatures indicated for that aircraft during European trials. The second level was full military power output of the J85-GE5 engine. The third level was full afterburner power.

#### (1) Post-European Jet Engine Tests

This test was performed to ascertain the resistance of Hetron 75/25-31/42 (subsequently 24505) to the P.1127 aircraft rated engine and was fabricated as follows:

(a) PEJET No. 1 - The actual spray time for this site was five minutes. The resin system was Hetron 75/25-31/42 promoted with 0.5% Cobalt Naphthenate and 0.05% dimethylaniline. Approximately 15-20 pounds of resin was lost in the pumping system. The resin was extremely cold (35°F) and was allowed to warm up for about 3 hours prior to spraying but was still fairly viscous. The catalyst consisted of one pound (0.5%) of Cadoc MDP (60% MEK<sub>2</sub> in dimethylphthalate). A clogged catalyst line produced poor dispersal of the catalyst which produced a non-uniformity of cure rate. Portions of the site yielded a Shore D hardness of 55 to 60 2.5 hours after fabrication. Other sections had not yet begun to cure at that point. This site contained approximately 8% PPG-533-60 roving. The site was test fired. The curve simulating P.1127 characteristics was used throughout. This site passed 10 full cycles of P.1127 aircraft rated engine without failure.

(b) PEJET No. 2 - This site was prepared in a similar manner as Site No. 1. The catalyst malfunction had been corrected but difficulty was experienced with the AFAPL pump. The net effect was a very intermittent pumping rate that required over 30 minutes for site fabrication. This site contained 7.5% PPG-533-60 roving and appeared to be of relatively good quality despite the pumping problems. (Note: Resin for this site had been stored in a heated area and was not overly viscous (4800 cps at 72°F). The site had a Shore D hardness of 30, one hour after fabrication, and Shore D 50, four hours after fabrication, when the engine test commenced. The resin system contained Hetron 75/25-31/42, with 14.0% H<sub>3</sub>BO<sub>3</sub>, 3.0% Sb<sub>2</sub>O<sub>3</sub> and 1.0% Cab-O-Sil (M-5). The engine test consisted of two cycles of the P.1127 power curve, two cycles of full military power, one short afterburner cycle and one full afterburner (7 seconds afterburner - 20 seconds total) cycle.

(c) PEJET No. 3 - This resin system used on this site was Hetron 75/25-31/42, with 28.0%  $H_3BO_3$ , 30%  $Sb_2O_3$  and 1.0% Cab-O-Sil (M-5). Extreme difficulties were encountered with the pump system. The quality of this site was poor. LTV personnel and the Air Force agreed that this site would not be tested.

(d) PEJET No. 4 - This site was a composite structure consisting of 2 lb/ft<sup>2</sup> Hetron 24505, 24 oz/yd<sup>2</sup> woven roving, and PPG-533-60 spray roving plus 2 lb/ft<sup>2</sup> of a thermal-erosion resistant resin and PPF-533-60 spray roving. The thermal-erosion resistant resin (Q-5) was composed as follows:

66% Hetron 75/25-353/42  
30%  $H_3BO_3$   
3%  $Sb_2O_3$   
1% Cab-O-Sil M-5

The site was subjected to 11 cycles of 20 seconds total, 6 seconds afterburner with the J85-GE5 jet engine. No failures occurred. Erosion in a severe cavitation area at the edge next to the concrete made it advisable to discontinue test. The test area of the site was in excellent condition at the cessation of testing.

(e) PEJET No. 5 - This site was fabricated using two layers of 24 oz/yd<sup>2</sup> woven roving. The outer area of the site was impregnated with Hetron 353 to compensate for resin lost in air shipment. The test area of the site was sprayed with Laminac 75/25 176-1/126-3 (with 0.75% Cobalt Naphthenate added). MEK peroxide (Cadox MDP) was hand-mixed (0.75%) into the resin (catalyst injection was not possible due to temporary loss of equipment in shipment). PPG-533-60 sprayed roving was sprayed concurrently with the resin. The site density was approximately 2.8 lb/ft<sup>2</sup> with 15% glass content (principally woven roving). This resin material had been stored for approximately three months in unlined containers and appeared to be near the end of its effective storage life. Consequently, the material underwent a more rapid liquid-gel transition (6 minutes) than had been predicted by tests performed when the resin was new. This site was cured to a firm gel (solid) within 15 minutes from preparation. The Shore D hardness was 60/55 in one hour and 80/80 when tested the next morning. The test was discontinued after 5 cycles at P.1127 rated engine because of delamination.

(f) PEJET No. 6 - This site was composed of 11.6% PPG-533-60 sprayed glass and Laminac 75/25 176/126 resin. This site passed 10 cycles of normal rated power plus 3 cycles of full military power. On cycle number 14, an 8-inch tear occurred in the blast area.

(g) PEJET No. 7 - This site was composed of one layer of 24 oz/yd<sup>2</sup> woven roving, to "layers" of PPG-533-60 sprayed roving and Hetron 24505 (.05 DMA added) resin. Some "run through" of resin was noted, but this was less than experienced with the Laminac material. This site passed 10 cycles of normal rated power (P.1127) plus 7 cycles of full military power. The site did not "fail" but pinholes which formed on cycle 17 indicated the advisability of cessation of testing. This system has the added advantage of giving an indication of when to perform repairs; i.e., the appearance of woven roving.

(h) PEJET No. 8 - This site was composed of Hetron 24505 resin, two layers of 24 oz/yd<sup>2</sup> woven roving and a cap of 1 lb/ft<sup>2</sup> resin with sprayed roving only. Total site density was 3 lb/ft<sup>2</sup> (Note: Each 1 lb/ft<sup>2</sup> layer was sprayed independently). This site appeared to have less resin "run through" than the one layer site above. This site was subjected to 10 cycles of normal rated power (P.1127) plus 12 cycles of full military power. On cycle 22, one layer of woven roving gave way. This occurred early in the cycle, and the engine operator allowed the engine to run the complete cycle. The net result was a lifting and gradual broadening of the fracture area but no catastrophic failure. This layer returned to nearly its original position when the engine power was cut off. The bottom 1 lb/ft<sup>2</sup> remained intact.

Torch test data may be found in Table III. PEJET results for individual sites are shown in Table IV.

#### i. Material Storage Stabilization

##### (1) Test Method

The test method for storage stability consisted of taking the ash content of the top and bottom layers of each sample formulation tested and recording the top/bottom ash content ratio after exposing the samples to dynamic aging. As the ash content ratio approaches zero, greater settling of fillers is indicated.

##### (a) Ash Content

This value was derived using ASTM method D-1506-59 using a burn-off temperature of 1200°F.

##### (b) Dynamic Aging

This test consisted of subjecting the sample to excessive centrifugal force in a centrifuge to accelerate the settling of fillers. This test cannot be applied directly to determine the storage

stability of resin compounds but can be used to derive relative comparisons to resin systems of known stability.

## (2) Test Results

Although the material developed under Phase I of this contract, referred to as B-3-B, had some disadvantages, it had very good storage stability. Therefore, this material has been included in this test as a reference point for the relative values obtained. Table V includes the B-3-B formulation as well as the two base resins used in this test. The formula number is assigned to each formulation as follows:

The first figure indicates the base resin used; hence, P indicates Durez 24505.

The second figure indicates the percent of boric acid used; hence, "1" indicates 0%, 2 indicates 7%, etc.

The third figure indicates the compounder of the formulation; hence, "L" indicates ITV's laboratory, "B" indicates Andrew Brown Co.

Any additional figures indicate a special variation in content.

Ideal stability would have a constant ratio of 1.0 from zero revolutions to 100,000 or more revolutions. Experience has shown that a ratio of 0.5 at 10,000 revolutions at 1667 rpm can be tolerated. Therefore, this point has been set as a minimum.

Using Table V as a guide, refer to Table VI for the following observations:

(a) Of the formulations given, other than B-3-B, Q5L exhibited the best storage stability.

(b) Despite the fact that Q5L and Q5B had the same proportions of fillers, Q5L was somewhat superior indicating better compounding in a small laboratory mill as compared to the larger commercial mill.

(c) The values given for 5000 revolutions are helpful in distinguishing between two materials which might have practically the same value at 10,000 revolutions.

TABLE III POST-EUROPE TORCH TEST DATA

MATERIAL SYSTEM	REINFORCEMENT		TORCH TEST	
	TYPE	% OF TOTAL	CYCLES	TIME (MIN.)
Hetron 75/25 - 31/42 Sb2O3 Cab-0-S11 (M-5) H3BO3 H3BO3 H3BO3 H3BO3 H3BO3 H3BO3	PFG-533-60 sprayed roving	10.0	12	5.47
		10.0	9	3.82
		10.0	6	2.83
		10.0	6	2.77
		10.0	4	1.73
		10.0	4	2.80
		10.0	6	
Hetron 75/25 - 353/42 Sb2O3 Cab-0-S11 (M-5) H3BO3 H3BO3 H3BO3 H3BO3 H3BO3	PFG-533-60 sprayed roving	9.1	9	4.13
		9.1	8	3.37
		9.1	8	3.79
		9.1	4	1.99
		9.1	4	1.85
		10.0	4	2.01
Hetron 75/25 - 31/42 Hetron 75/25 - 353/42 Hetron 50/50 - 31/42	PFG-533-60 sprayed roving PFG-533-60 sprayed roving PFG-533-60 sprayed roving	10.0 9.1 10.0	4 4 6	1.91 2.68
Hetron 75/25 - 353/42 Sb2O3 Cab-0-S11(M-5) H3BO3	PFG-533-60 sprayed roving PFG-533-60 sprayed roving PFG-533-60 sprayed roving	8.0 8.0 30.0%	10 9	4.50 4.07

TABLE III POST-EUROPE TORCH TEST DATA (Concluded)

MATERIAL SYSTEM	REINFORCEMENT		CYCLES	TORCH TEST TIME (MIN.)
	TYPE	% OF TOTAL		
Hetron 75/25 - 353/42 Sb203 - 3.0% Cab-0-S11(M-5) 1.0% H3B03 - 30.0%	PPG-533-60 sprayed moving on top layer	5.2	9	3.85
	24 oz/yd <sup>2</sup> woven roving on bottom layer	5.3	12	5.49
Hetron 90/10 - 353/42 Sb203 - 3.0% Cab-0-S11(M-5) 1.0% H3B03 - 30.0%	PPG-533-60 sprayed roving	8.0	8	3.76
	PPG-533-60 sprayed roving	8.0	12	5.03
	PPG-533-60 sprayed roving on top layer	5.2	12	5.52
	24 oz/yd <sup>2</sup> woven roving on bottom	5.3	9	3.82
B-3-B (Formula)	PPG-533-60 sprayed roving	8.0	10	4.57
	PPG-533-60 sprayed roving	8.0	12	5.08
	PPG-533-60 sprayed roving on top layer	5.3	8	3.78
	24 oz/yd <sup>2</sup> woven roving on bottom layer	5.3	10	4.63

TABLE IV POST-EUROPE JET ENGINE EXHAUST IMP.

TEST NUMBER AND DATE COMPLETED	PAD DENSITY LB/FT <sup>2</sup>	MATERIAL SYSTEM	TYPE AND PERCENT (%) REINFORCEMENT	SITE TEMPERATURE °
PJET 1 2-15-66	2.5	Hetron 75/25 - 31/42	PPG-533-60 sprayed roving ~ 8.0%	837
PJET 2 2-16-66	2.5	Hetron 75/25 - 31/42 H <sub>3</sub> BO <sub>3</sub> - 14.0% Sb <sub>2</sub> O <sub>3</sub> - 3.0% Cab-O-Sil (M-5) - 1.0%	PPG-533-60 sprayed roving ~ 7.5%	837 1197 1197 1197
PEJET 3 2-17-66	2.5	Hetron 75/25 - 31/42 H <sub>3</sub> BO <sub>3</sub> - 28.0% Sb <sub>2</sub> O <sub>3</sub> - 3.0% Cab-O-Sil (M-5) - 1.0%	PPG-533-60 sprayed roving ~ 7.5%	-
PEJET 4 3-22-66	2.0 2.0	Hetron 75/25 - 31/42  (Composite) Hetron 75/25 - 353/42 H <sub>3</sub> BO <sub>3</sub> - 30.0% Sb <sub>2</sub> O <sub>3</sub> - 3.0% Cab-O-Sil (M-5) - 1.0%	24 oz/yd <sup>2</sup> woven roving ~ 11.2  PPG-533-60 sprayed roving ~ 7.5%	1197
PEJET 5 4-1-66	3.0	Laminac 176-1/126-3 75/25%	PPG-533-60 sprayed roving ~ 4.0% 24 oz/yd <sup>2</sup> woven roving ~ 14.0% (bottom)	832

A

IMPINGEMENT TEST DATA SUMMARY

TEMPERATURE °F	SITE PRESSURE PSF	SITE VELOCITY FPS	NUMBER CYCLES	RESULTS
7	706	1660	10 (1)	<p><u>Cycles 1-5</u> Resin eroded sweeping out glass fibers; char developed</p> <p><u>Cycles 6-7</u> Some reticulation in char</p> <p><u>Cycles 8-9</u> Slight flutter incurred</p> <p><u>Cycle 10</u> No change; no failure; test terminated</p>
7	706	1660	2 (1)	Slight char; some erosion of resin; sweeping away of glass fibers
7	1400	1940	2 (2)	Same as above; cherry red 3rd and 4th cycle
7	1400	1940	1 (3)	No change
7	1400	1940	1 (4)	Erosion in hot area; test terminated
			<u>6</u>	
	-	-	-	Equipment and materials not compatible.
07	1400	1940	11 (4)	<p>Heavy char on 1st cycle. Slight cavitation after 2nd cycle. Increased cavitation on 3rd cycle Uniform char with long fissures forming in char after 4th cycle No change on 5-7th cycle. Erosion near cement column on 8th-9th cycle. Test terminated; failure.</p>
32	716	1680	5 (1)	<p>Cycle No. 1 - Six-second run; shut down for repairs. Cycle No. 2 - Much smoke; glass leaching out; woven roving exposed. Cycle No. 3 - Woven roving exposed in area 28 x 15 inches Cycle No. 4 - Resin cooked out of upper layer of woven roving. Cycle No. 5 - Delaminated; Test discontinued.</p>

B

TABLE IV POST-EUROPE JET ENGINE EXHAUST IMPINGEMENT

TEST NUMBER AND DATE COMPLETED	PAD DENSITY LB/FT <sup>2</sup>	MATERIAL SYSTEM	TYPE AND PERCENT (%) REINFORCEMENT	SITE TEMPERATURE
PEJET 6 4-12-66  e	3.0	Laminac 176-1/126-3 75/25%	PPG-533-60 sprayed roving ~ 11.2%	822 1197
PEJET 7 4-13-66	3.0	Hetron 24505 (Factory mixed 7525 31/42)	PPG-533-60 sprayed roving ~ 5.7% 24 oz/yd <sup>2</sup> woven roving ~ 13.5% (bottom)	840 1197
PEJET 8 4-14-66	3.0	Hetron 24505	PPG-533-60 sprayed roving ~ 5.0% 24 oz/yd <sup>2</sup> woven roving ~ 15.0% (bottom)	840 1197
<p style="text-align: center;">NOTE</p> <p>(1) P.1127 Power Curve                      (2) Full Military Power                      (3) Short Afterburner Cycle                      (4) Full Afterburner, 7 sec. AB-20 seconds total</p>				

A

AUST IMPINGEMENT TEST DATA SUMMARY (Concluded)

SITE TEMPERATURE °F	SITE PRESSURE PSF	SITE VELOCITY FPS	NUMBER CYCLES	RESULTS
822 1197	701 1401	1640 1940	10 (1) <u>4</u> (2) 14	Cycle No. 1-2 - Resin ablation and glass fiber blown from surface. Cycles No. 3-5 - Increase in char Cycles No. 6-9 - Increasing glass bleedout Cycle No. 10 - No failure Cycle No. 11 - Much smoke, severe erosion Cycles No. 12-13 - Increasing erosion Cycle No. 14 - Pad failed; 8-inch tear; pad was approximately 1/8-inch thick at tear line.
840 1197	733 1410	1705 1940	10 (1) <u>7</u> (2) 17	Cycle No. 1 - Resin ablation; glass fiber swept out on surface. Cycle No. 2 - Good char developed Cycles No. 3-6 - No change Cycle No. 7 - Slight glass ablation Cycles No. 8-9 - Char reticulation increase Cycle No. 10 - Slight bleedout. Cycles No. 11-12 - Impingement area cherry red; charred area increased from 45 to 48-inch diameter. Cycles No. 13-14 - No change Cycles No. 15-16 - Woven fabric exposed Cycle No. 17 - 10 pinholes in a 6-inch diameter ring; test terminated
840 1197	728 1410	1690 1940	10 (1) 12 (2)	Cycle No. 1 - Charring developed Cycle No. 2 - Charring increased Cycles No. 3-10 - Good char; no woven roving showing. Cycle No. 11 - Slight glass ablation on surface Cycle No. 12 - Red glow Cycles No. 13-15 - No change Cycle No. 16 - Woven roving showing Cycles No. 17-19 - No change Cycle No. 20 - Some white glass showing at seam Cycle No. 21 - 6-inch diameter of woven roving removed Cycle No. 22 - Delamination of top layer of woven roving cloth; test discontinued.

B

TABLE V CENTRIFUGE TEST RESULTS T/B RATIO VS REVOLUTIONS

- ⊙ B-3-B
- P3B
- △ P4B
- × Q5L
- ⊗ Q5B
- \* Q4L
- Q5LI

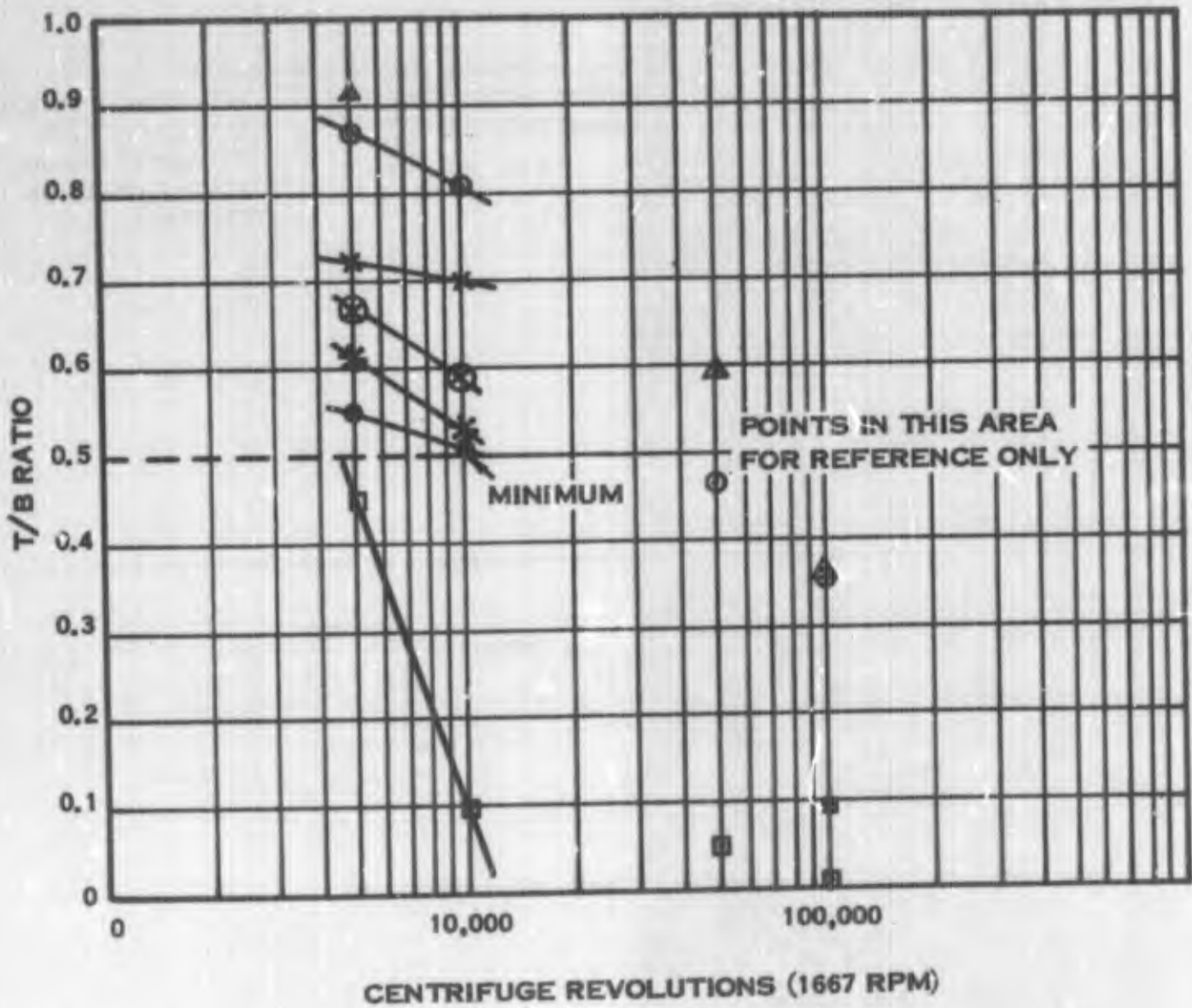


TABLE VI COMPOSITION OF 9 FORMULATIONS - % COMPOSITION

Formula No.	Formulation
P1	Durez 24505 75 Hetron 31, 25 Hetron 42 (no fillers) not centrifuged
P3B	Ball milled by Andrew Brown Company 82.5 Durez 24505, 14 H <sub>3</sub> BO <sub>3</sub> , 3 Sb <sub>2</sub> O <sub>3</sub> , 0.5 Cab-O-Sil M-5
P4B	Ball milled by Andrew Brown Company 68.5 Durez 24505, 28 H <sub>3</sub> BO <sub>3</sub> , 3 Sb <sub>2</sub> O <sub>3</sub> , 0.5 Cab-O-Sil M-5
Q1	Mixture of Hetron 353 and 42 resins 75 Hetron 353, 25 Hetron 42 (no fillers) not centrifuged
Q4L	Ball milled in laboratory 66-Q1, 28 H <sub>3</sub> BO <sub>3</sub> , 4.5 Sb <sub>2</sub> O <sub>3</sub> , 1.5 Cab-O-Sil M-7
Q5L	Ball milled in laboratory 66-Q1, 30 H <sub>3</sub> BO <sub>3</sub> , 3 Sb <sub>2</sub> O <sub>3</sub> , 1.0 Cab-O-Sil M-5
Q5B	Ball milled by Andrew Brown Company 66-Q1, 30 H <sub>3</sub> BO <sub>3</sub> , 3 Sb <sub>2</sub> O <sub>3</sub> , 1.0 Cab-O-Sil M-5
Q5L1	Ball milled in laboratory 66-Q1, 30 H <sub>3</sub> BO <sub>3</sub> , 3 Sb <sub>2</sub> O <sub>3</sub> , 0.5 Cab-O-Sil M-5
Q5B1	Ball milled by Andrew Brown Company 66-Q1, 30 H <sub>3</sub> BO <sub>3</sub> , 3 Sb <sub>2</sub> O <sub>3</sub> , 0.5 Cab-O-Sil M-5
B-3-B	Ball milled by Andrew Brown Company 56 Hetron 353, 32 H <sub>3</sub> BO <sub>3</sub> , 5.5 Antimony, 2 Cab-O-Sil M-7

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## SECTION III

### 3.0 APPLICATION EQUIPMENT

#### 1. SUMMARY

Application equipment capable of preparing full-scale VTOL landing sites was designed, fabricated, and modified during the Phase I effort. This equipment was mobile over improved and unimproved surfaces, was self sufficient in the field, and contained required subsystems for dispensing of raw materials.

The equipment concept and arrangement was based on studies conducted during Contract AF33(615)-2367 (Reference(2)). The design effort was directed at obtaining demonstration equipment that was reasonably lightweight, air transportable, and utilizing off-the-shelf components to the maximum extent possible in order to expedite early tests of a full-scale system.

The equipment consists of a prime mover vehicle, four resin tank trailers, and miscellaneous equipment. The prime mover includes an air compressor, dual resin pumps, catalyst injection equipment, fiberglass reinforcement spray applicators, spray hoses, and associated monitoring and control equipment. Two complete systems for applying catalyzed resin and fiberglass were provided, each with individual controls.

The equipment was designed and fabricated early in Phase I, and was ready for operations only 2 1/2 months after contract go-ahead. Following site applications in England and Germany, modifications were designed and fabricated during the latter part of Phase I. These modifications were incorporated to correct excessive pressure losses in the resin system, to improve operational characteristics, and to add certain equipment items where needed to permit use of rolled fiberglass roving and unfilled resin. Details of these modifications are presented in subsequent paragraphs.

In order to identify the equipment designs, the application equipment as used in England and Germany has been designated "Pre-Europe," while the modified equipment is referred to as "Post-Europe." These terms will appear in subsequent paragraphs and on copies of LTV drawings included in this report.

#### 2. PRE-EUROPE CONCEPT STUDIES

Six basic application system concepts were evaluated under the previous contract. These systems were analyzed and compared for ground mobility, total system weight, number of vehicles required, versatility (adaptability of system to other uses or variations in total material

quantity), probable cost and lead time for development, and various other factors. As a result of these trade-offs, a system concept was selected which was optimized for the follow-on test programs in which further development of materials and techniques was of primary concern. The selected concept was capable of being rapidly assembled, versatile in regard to application technique used, air-transportable and demonstrated adequate off-road mobility. The prime mover selected was a four-wheel drive truck (Figure 7) capable of supplying adequate power to drive all subsystems by utilizing the truck engine through a power takeoff unit. Four tank trailer trucks were provided to transport the necessary quantity of liquid resin material (Figure 8).

### 3. PRE-EUROPE EQUIPMENT DESCRIPTION

#### a. Prime Mover - Truck

A Dodge WM-300 Power Wagon, four-wheel drive vehicle was procured and modified to accept the Rapid Site application equipment. The general arrangement of this equipment is shown in Figure 9. This commercial vehicle was equipped with a power takeoff, winch, limited slip differentials, and a 125 hp six-cylinder engine. Basic vehicle details are shown in Figure 10 and a weight breakdown of the added equipment is shown in Figure 11.

#### b. Tank Trailers

Four 400-gallon tank trailers were designed and fabricated for transport of the liquid material to the site. These trailers were designed to be compatible in size, weight, and volume with the prime mover. A general arrangement drawing for the tank trailer is shown in Figure 12. The tank is a nominal 400-gallon capacity, fabricated of commercial steel. The tank ends are removable for cleaning and the interior is lined with a corrosion preventative coating. Two hatches are provided at the top for access to clean or inspect the tank. Provisions are made for mounting air driven resin mixers through these access hatches, if required. Resin outlet valves are provided at each end of the tank. A four-wheeled running gear was provided composed of standard off-the-shelf components. The trailer tires selected were the same size as those used on the prime mover to reduce spare requirements and to provide off-road mobility. The rear wheels were provided with electric running brakes and manual parking brakes. All running gear components were designed for highway and cross country conditions. An aft pintle hook was provided on each trailer to permit towing of two trailers in tandem over improved surfaces, and brake and running lights were also provided on each trailer. A resin delivery hose of adequate length connects the trailer to the prime mover pump suction system.

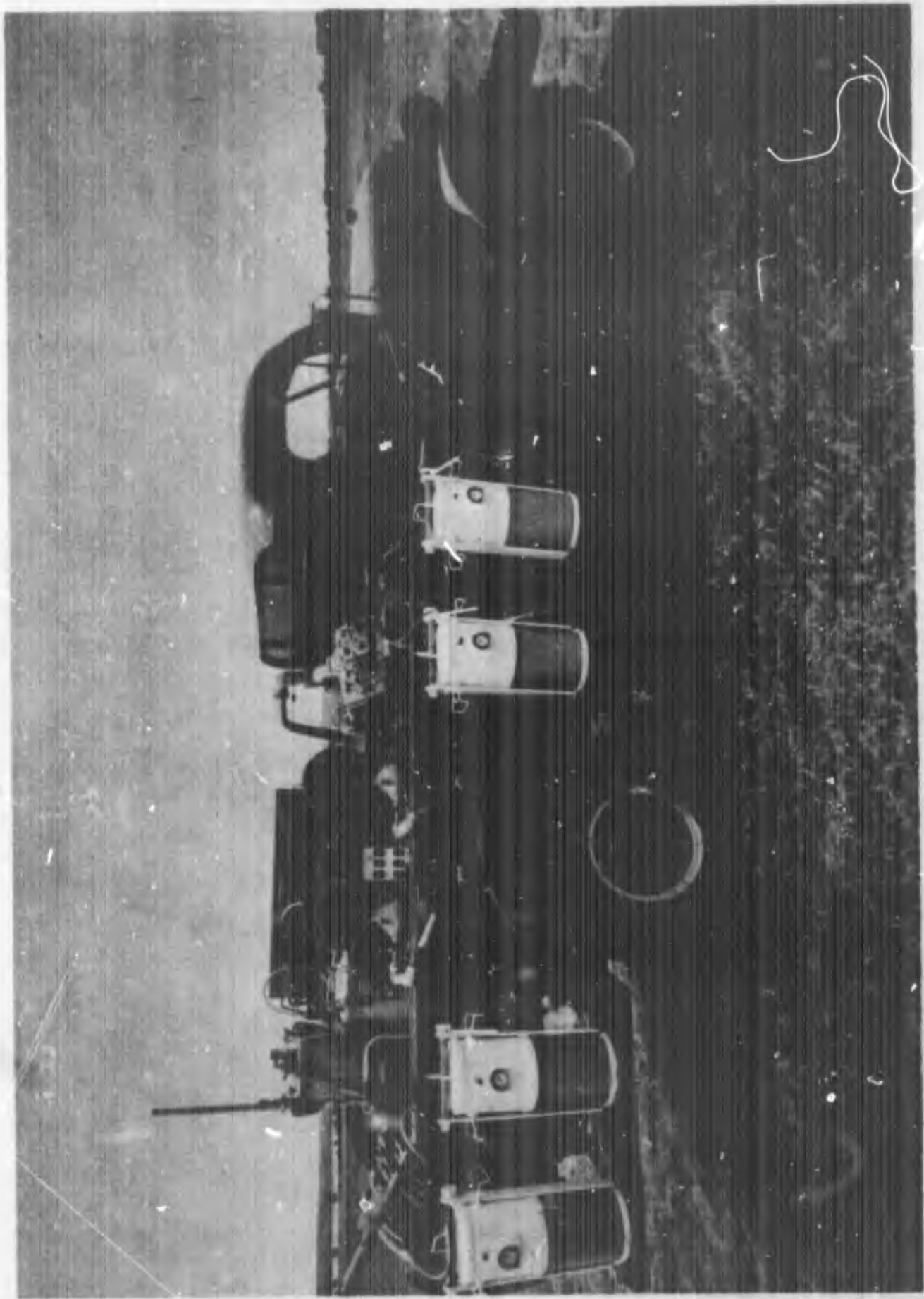


Figure 7. Truck, Dodge WM-300 Four-Wheel Drive Power Wagon

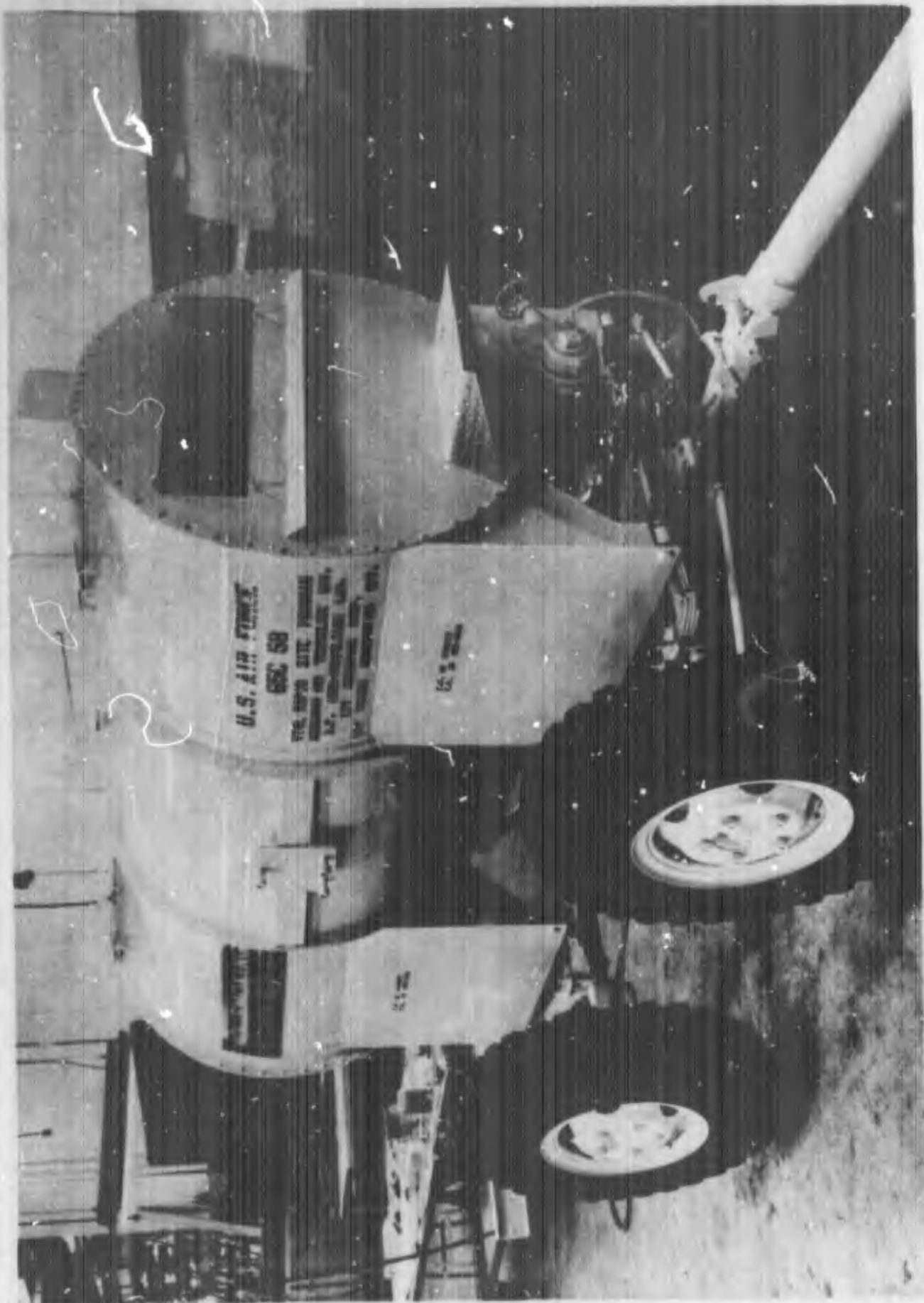
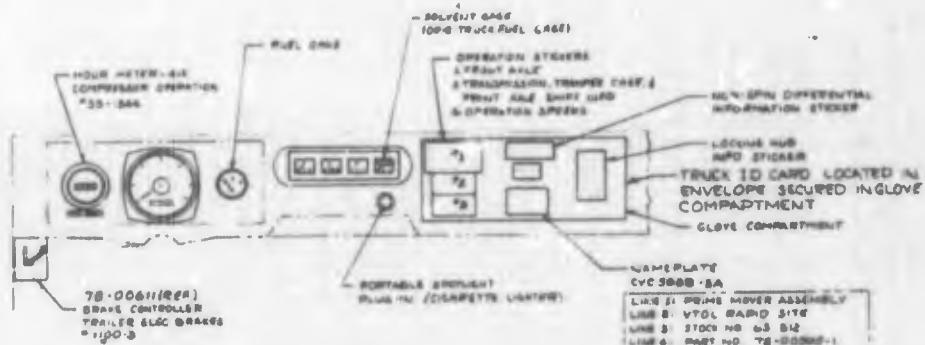
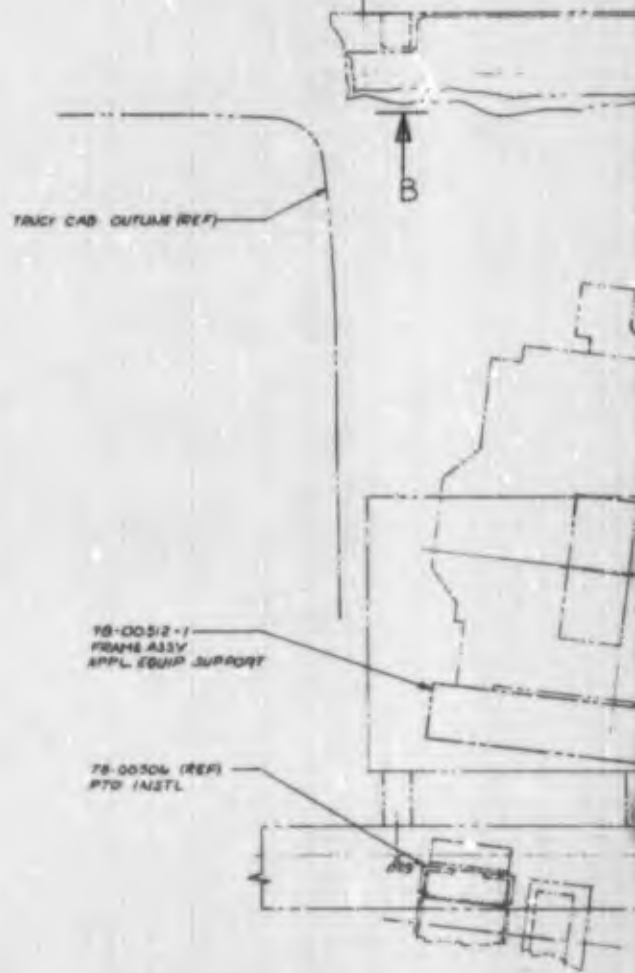
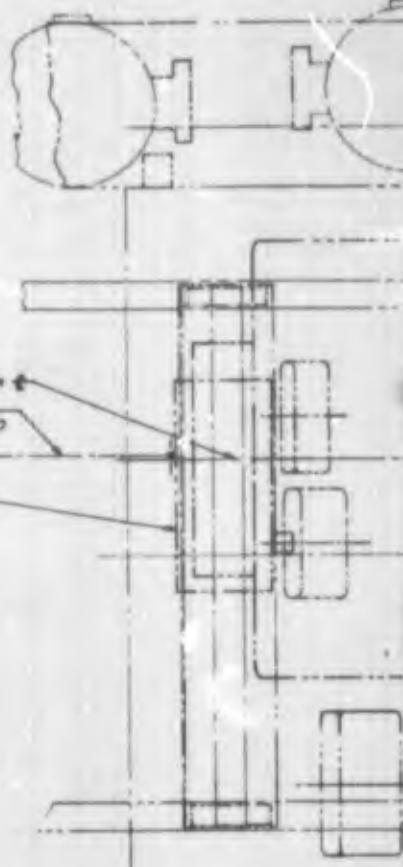


Figure 8. Tank Trailer Assembly



SECT C-C  
SCALE 1/4  
TRUCK DASH BOARD ARRANGEMENT

NAMEPLATE  
CVC 5000-BA  
LINE 1: PRIME MOVER ASSEMBLY  
LINE 2: VTOL RAMP SITE  
LINE 3: STOCK NO 63 512  
LINE 4: PART NO 78-00500-1  
LINE 5: CONTRACT  
LINE 6: SERIAL NO 1  
LINE 7: FOR VTOL RAMP SITE  
LINE 8: APPLICATION EQUIP ONLY  
LINE 9: WELD: 2000 LER



78-00614	BRAKE ASSY RESIN PUMP
78-00611	WIRING DIAG BRAKE CONTRL, BRAKES & LIGHTS
78-00610	PLUMBING INSTL
78-00603	AIR RECEIVER INSTL
78-00602	HOSE RACK
78-00601	TIE-DOWN, GLASS POTS
78-00600	FUEL TANK ASSY
78-00527	R.T.O. SHIFR MECHANISM
78-00526	SOIL DISC
78-00523	TRUCK BED COVER ASSY
78-00522	RESIN PLUMBING INSTL
78-00521	SOLVENT & CATALYST POT INSTL
78-00520	OPERATORS SEAT INSTL
78-00518	PULLEY ASSY IDLER
78-00517	CANCELLED
78-00516	PANEL ASSY OPERATORS CONTROL
78-00515	PLATFORM ASSY REAR FENDER
78-00513	APPLICATION EQUIP INSTL
78-00512	FRAME ASSY APPLICATION EQUIP SUPPORT
78-00511	CANCELLED
78-00510	SYS SCHEMATIC, VENDOR COMPONENTS
78-00508	POWER TRANSFER SCHEMATIC
78-00507	POWER TRANSFER INSTALLATION
78-00506	PTO INSTALLATION
78-00502	MARUNG DIAGRAM
DWG. NO.	TITLE

ACCUMULATION TABLE  
VTOL RAPID SITE PRIME MOVER (78-00500-1)

A

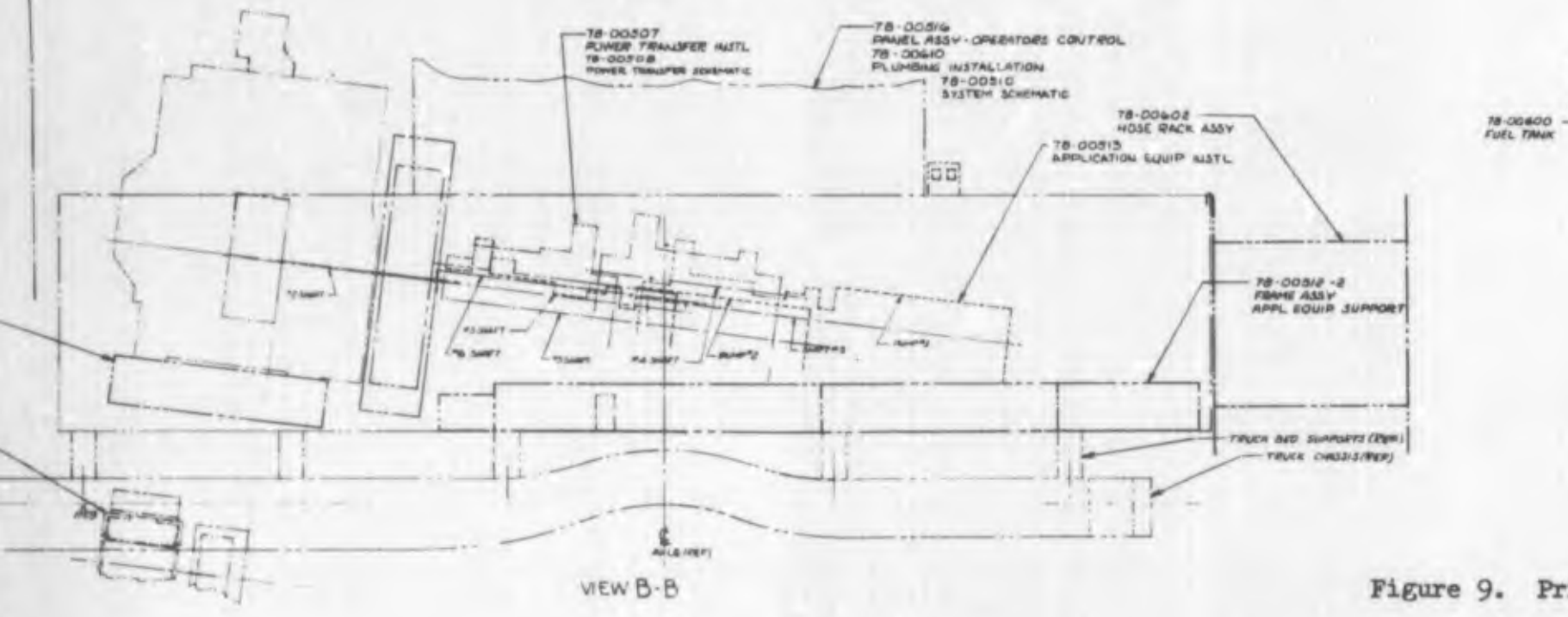
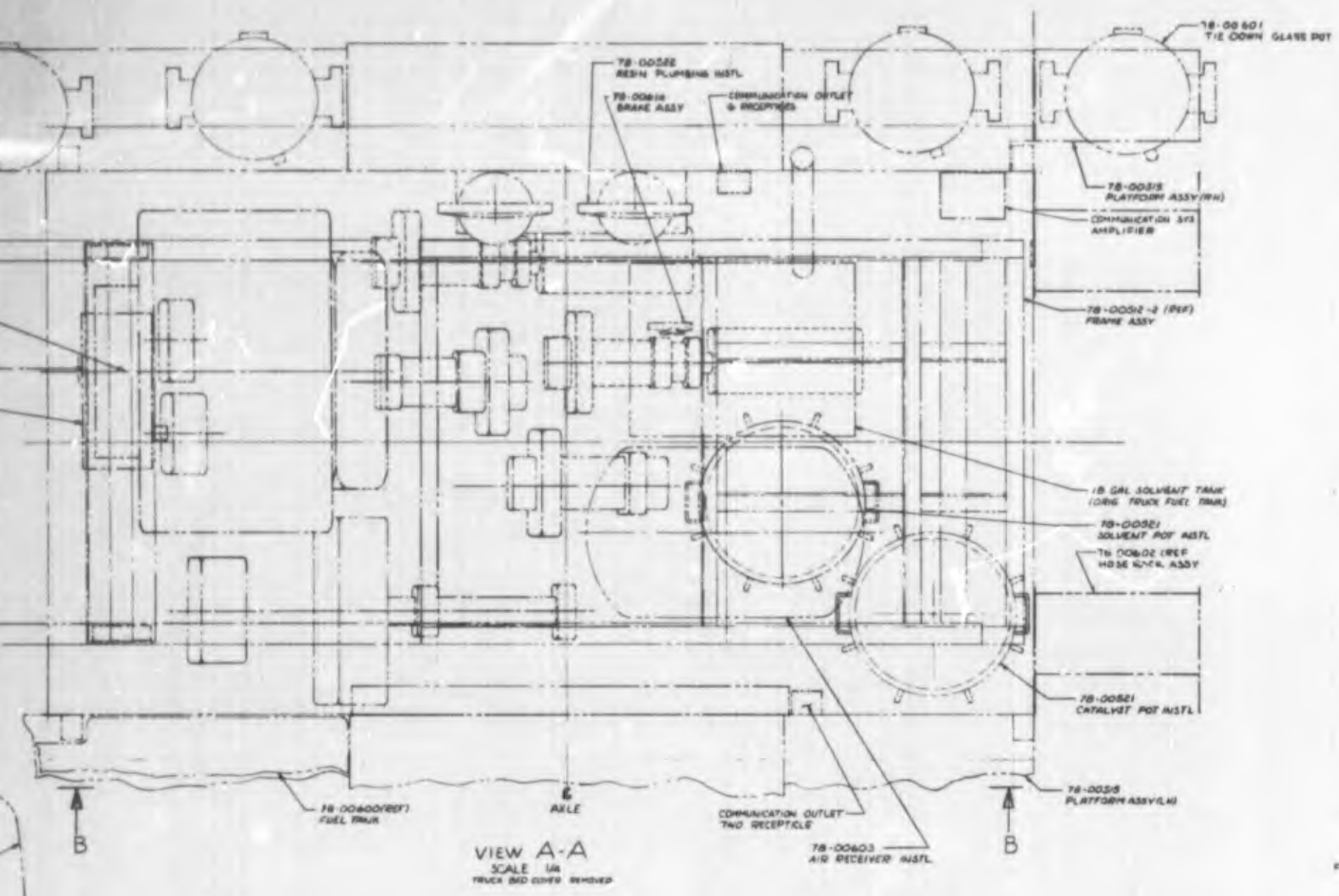
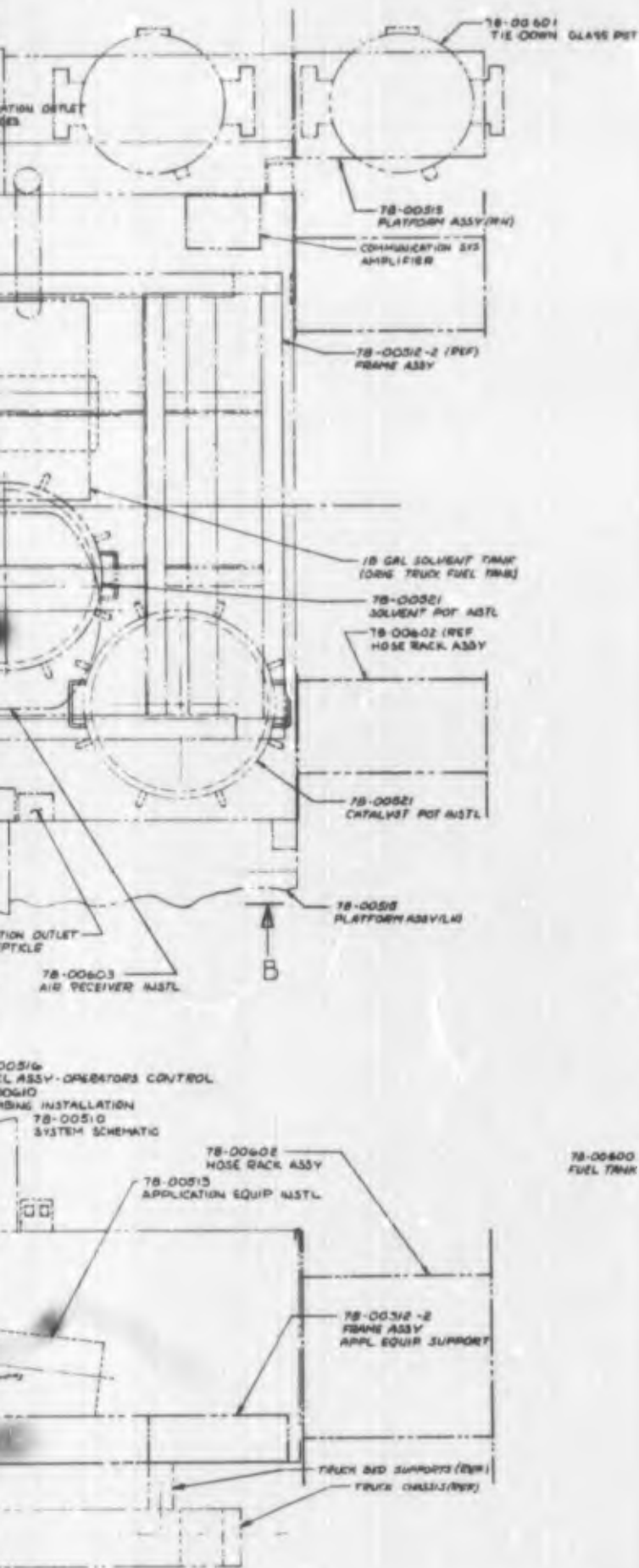


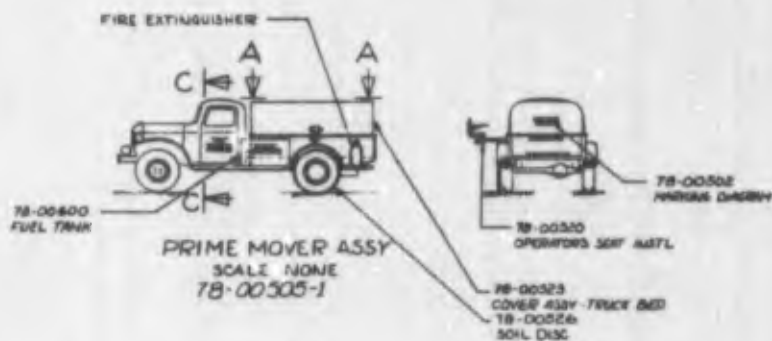
Figure 9. Prime

B



**NOTE :**

1. PRIME MOVER ENVELOPE
  - A. SHIPPING 10N WHEELS - 210 LG X 80W X 79 HIGH ON SKID
  - B. OPERATIONAL: 227 LG X 102 W X 79 HIGH
2. ALL EQUIPMENT INSTALLED ON PRIME MOVER IS COMMERCIAL EQUIPMENT AND ALL MAINTENANCE AND SERVICE WILL BE IN ACCORDANCE WITH MANUFACTURER DOCUMENTATION
3. OPERATION OF APPLICATION SYSTEM AS INSTALLED ON PRIME MOVER TO BE IN ACCORDANCE WITH "EQUIPMENT OPERATION INSTRUCTIONS - RAPID SITE" MANUAL AS PREPARED BY ENGINEERING.
4. FRAMEWORK, WITH SAFETY GRATING, USED TO COVER THE TRANSFER SYSTEM AND ALSO UTILIZED AS STORAGE PLATFORM FOR GLASS POTS DURING TRANSIT PERIODS IS NOT SHOWN
5. PRIME MOVER SHIPPING SKID WT 1300 LBS
6. PRIME MOVER WEIGHT DATA:
  - A. AS RECEIVED PRIOR TO MODIFICATION - 5230 LB.
  - B. SHIPPING CONFIGURATION - 9290 LB (WITH WHEELS AND WITH OUT HOSES, HOSE RACKS, FIBER GLASS POTS AND COMMUNICATIONS SET)
  - C. EST SHIPPING WT - 8900 LB
7. SHIPPING CONFIGURATION: PRIME MOVER WITH APPLICATION EQUIP INSTALLED, TRUCK BED COVER, FIBER GLASS POTS, HOSES (DRAINED), HOSE RACKS, COMMUNICATIONS SET, OPERATORS SEAT ALL STOWED AND SECURED TO SHIPPING SKID. PRIME MOVER WHEELS TO BE REMOVED FOR SHIPMENT, AND ALL HOSES, FLUID POTS & TANKS DRAINED



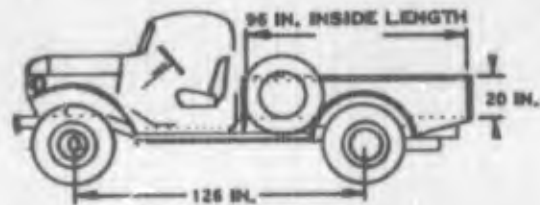
0 1 2 3 4 5 6 7 8 9 10 11  
 SCALE 1/4" = 1'

Figure 9. Prime Mover Assembly Rapid Site

C

## DODGE WM-300 MILITARY TYPE

MANY WORLD WAR II MODELS OF THIS FAMOUS WORKHORSE ARE STILL IN USE, AND ITS DESIGN REMAINS A FAVORITE WITH MANY TRUCK USERS BECAUSE OF ITS OUTSTANDING DAY-AFTER-DAY STAMINA. THE RUGGED 125 HP DODGE 251 SIX PROVIDES THE POWER, TEAMED WITH A 4-SPEED SYNCHRO-SHIFT TRANSMISSION. THE WM-300 IS AVAILABLE AS A ○UTILINE PICKUP WITH AN 8-FOOT BODY (SHOWN ABOVE) AND AS A ○CHASSIS-CAB OR ○CHASSIS-COWL. ALL HAVE A 126 IN. WHEELBASE AND GVW RATINGS OF 8,700 OR 9,300 LB.



DODGE WM-300 MILITARY TYPE

### STANDARD EQUIPMENT

- . 125 HP DODGE 251 SIX ENGINE
- . OIL FILTER
- . 35-AMP ALTERNATOR
- . CLOSED CRANKCASE VENTILATION
- . 4-SPEED SYNCHRO-SHIFT TRANSMISSION
- . 2-SPEED TRANSFER CASE
- . 4.51 SECTION MODULUS FRAME
- . 3,750-LB FRONT AXLE
- . 6,300-LB REAR AXLE
- . 215 SQ IN. OF BRAKE LINING
- . 11 IN. CLUTCH
- . 1,500-LB FRONT SPRINGS (AT PAD)
- . 3,000-LB REAR SPRINGS (AT PAD)
- . FRONT SHOCK ABSORBERS
- . CHANNEL-TYPE FRONT BUMPER
- . DOOR LOCKS
- . VINYL SEAT UPHOLSTERY
- . DRIVER'S ARMREST
- . DUAL SUN VISORS
- . RUBBER CAB FLOOR MAT WITH JUTE PAD
- . VACUUM WINDSHIELD WIPERS
- . WHEEL WRENCH

WHEELBASE	126 IN.
NOMINAL BODY LENGTH	8 FT
INSIDE LENGTH	96 IN.
INSIDE WIDTH (MAX)	54 IN.
WIDTH BETWEEN WHEELHOUSINGS	49 IN.
HEIGHT OF SIDES, TAILGATE	20 IN.
CAPACITY	58 1/2 CU FT

### SELECTED OPTIONAL EQUIPMENT

- . FRONT-MOUNTED 10,000 LB WINCH
- . FRONT TOW HOOKS
- . 40-AMP ALTERNATOR
- . RADIATOR OVERFLOW TANK
- . REAR SHOCK ABSORBERS
- . TACHOMETER
- . VACUUM BOOSTER HYDRAULIC BRAKES
- . 4-SPEED TRANSMISSION WITH POWER TAKEOFF, OFF OF TRANSFER CASE TO OPERATE FRONT END WINCH OR FOR OTHER PURPOSES
- . FRONT AND REAR END DRAW BAR (PINTLE)
- . DUAL MIRRORS (LONG ARM) 5 IN. X 7 IN.
- . RECIRCULATING HEATER
- . DIRECTIONAL SIGNALS
- . FRONT WHEEL LOCK OUT HUBS

Figure 10. Truck, Dodge WM-300 Power Wagon, General Arrangement

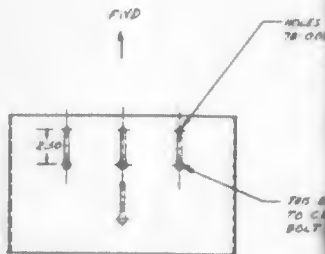
	<u>Weight</u>
Truck, Empty . . . . .	5,230
Frames	
Compressor . . . . .	150
Pump . . . . .	350
PTO & MIG BKTS (w/Pulley) . . . . .	150
Compressor and Receiver . . . . .	1,025
Resin Pumps . . . . .	80
Resin Pump Shafts, Pulleys, Belts, Shield . . . . .	220
Control Panel (w/Valves) . . . . .	40
Resin Flow Meters . . . . .	50
Resin Plumbing and Valves . . . . .	250
Catalyst, Air, Solvent Plumbing . . . . .	250
Catalyst Pot . . . . .	120
Solvent Pot . . . . .	90
Fuel Tank . . . . .	150
Glass Pots . . . . .	480
Hoses and Storage Rack . . . . .	170
Material	
Catalyst . . . . .	100
Solvent . . . . .	108
Fiberglass . . . . .	120
Fuel . . . . .	120
Cover . . . . .	50
Fire Extinguisher . . . . .	100
Fender Extensions, Oper. Seat, Misc. Bkts, Cookie Cutter Mtg. Plate . . . . .	330
Total	9,898

Figure 11. Estimated Weight Breakdown, Prime Mover Rapid Site Application Equipment

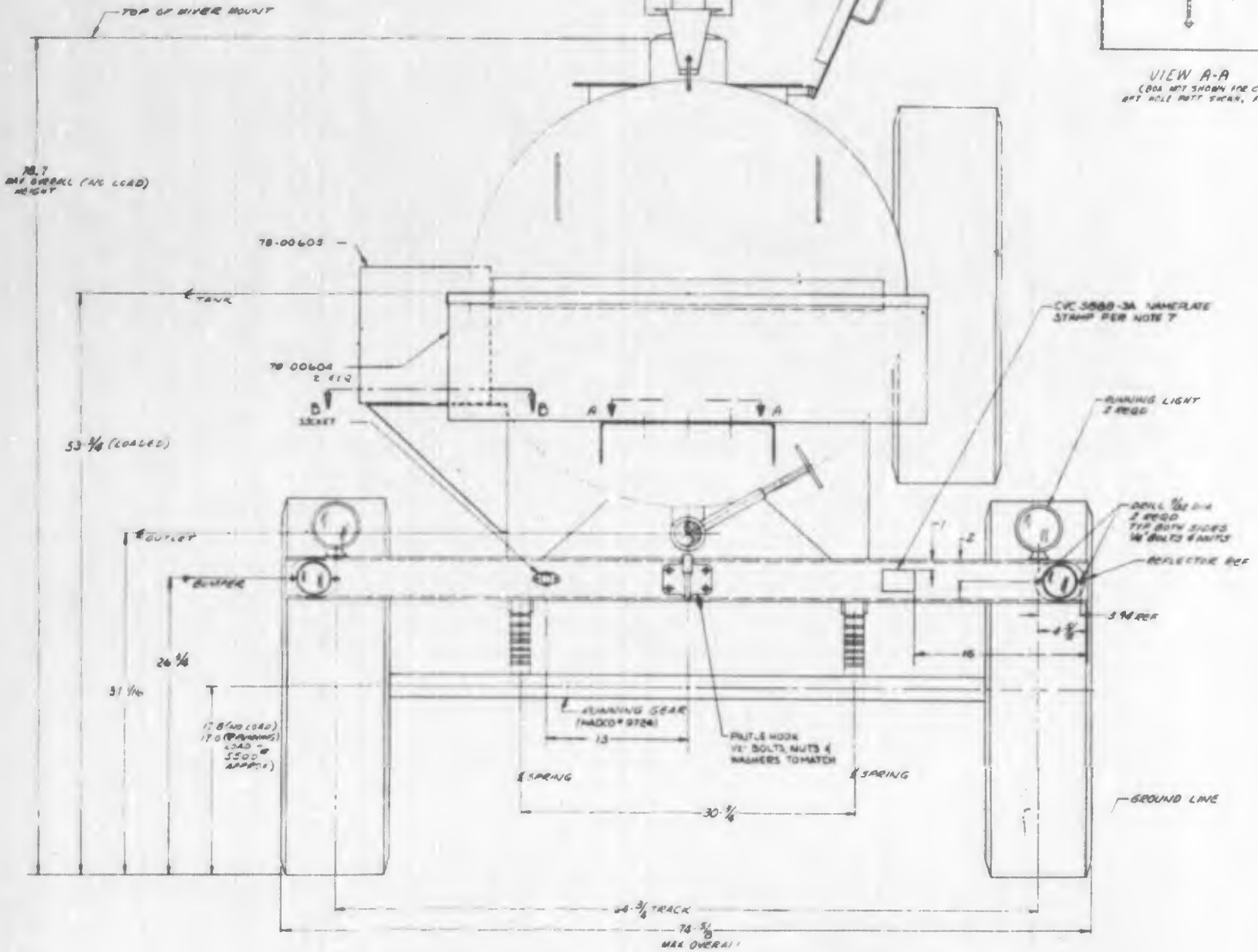


SECT B-B

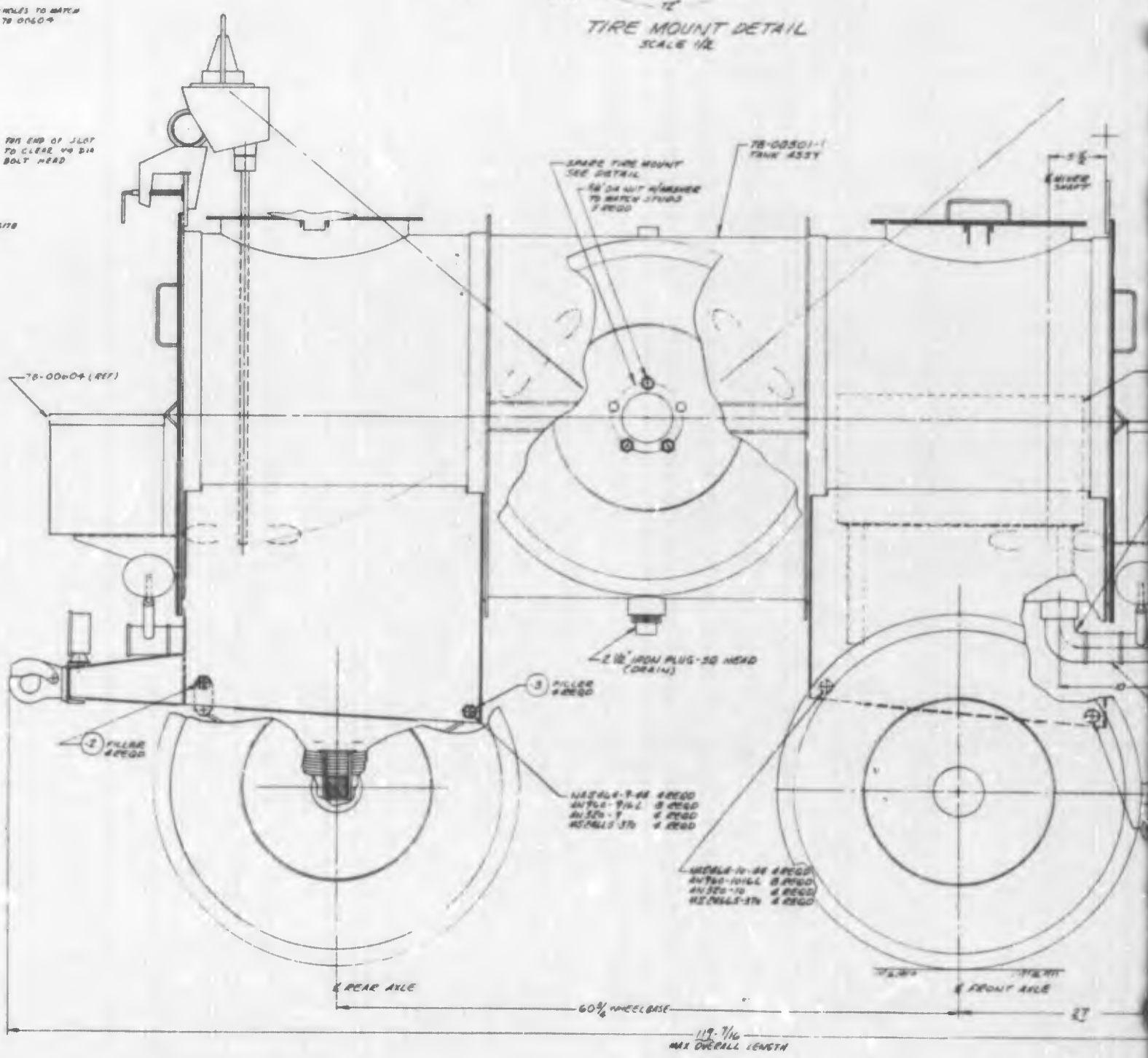
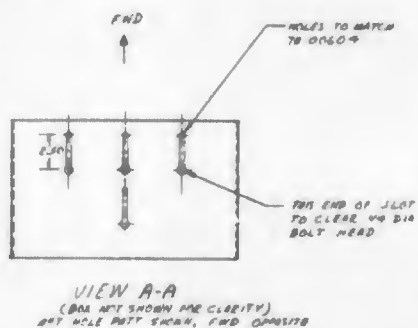
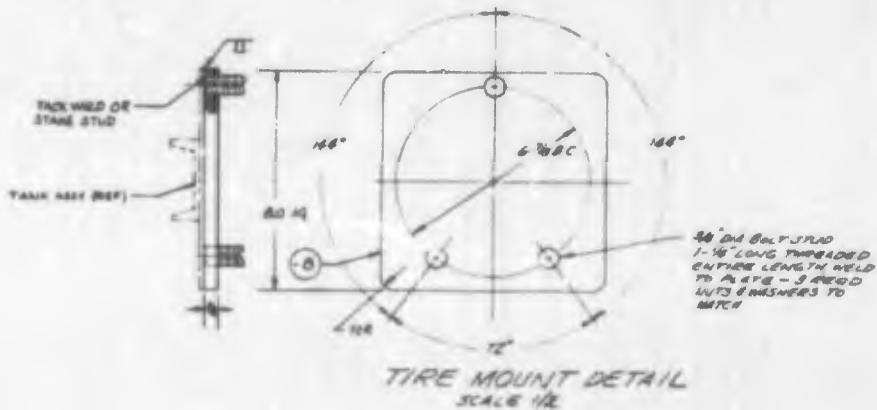
PORTABLE MIXER REF



VIEW A-A  
(DO NOT SHOW FOR CLARITY)  
BUT HOLE NOT SHOWN, FIVE OPPOSITE



A



5000-3A NAMEPLATE  
MP PER NOTE 7

RUNNING LIGHT  
2 REQD

DRILL 1/2 DIA  
2 REQD  
TYP BOTH SIDES  
IN BOLTS & NUTS

REFLECTOR REF

3 1/4 REF

GROUND LINE

Figure 12

B

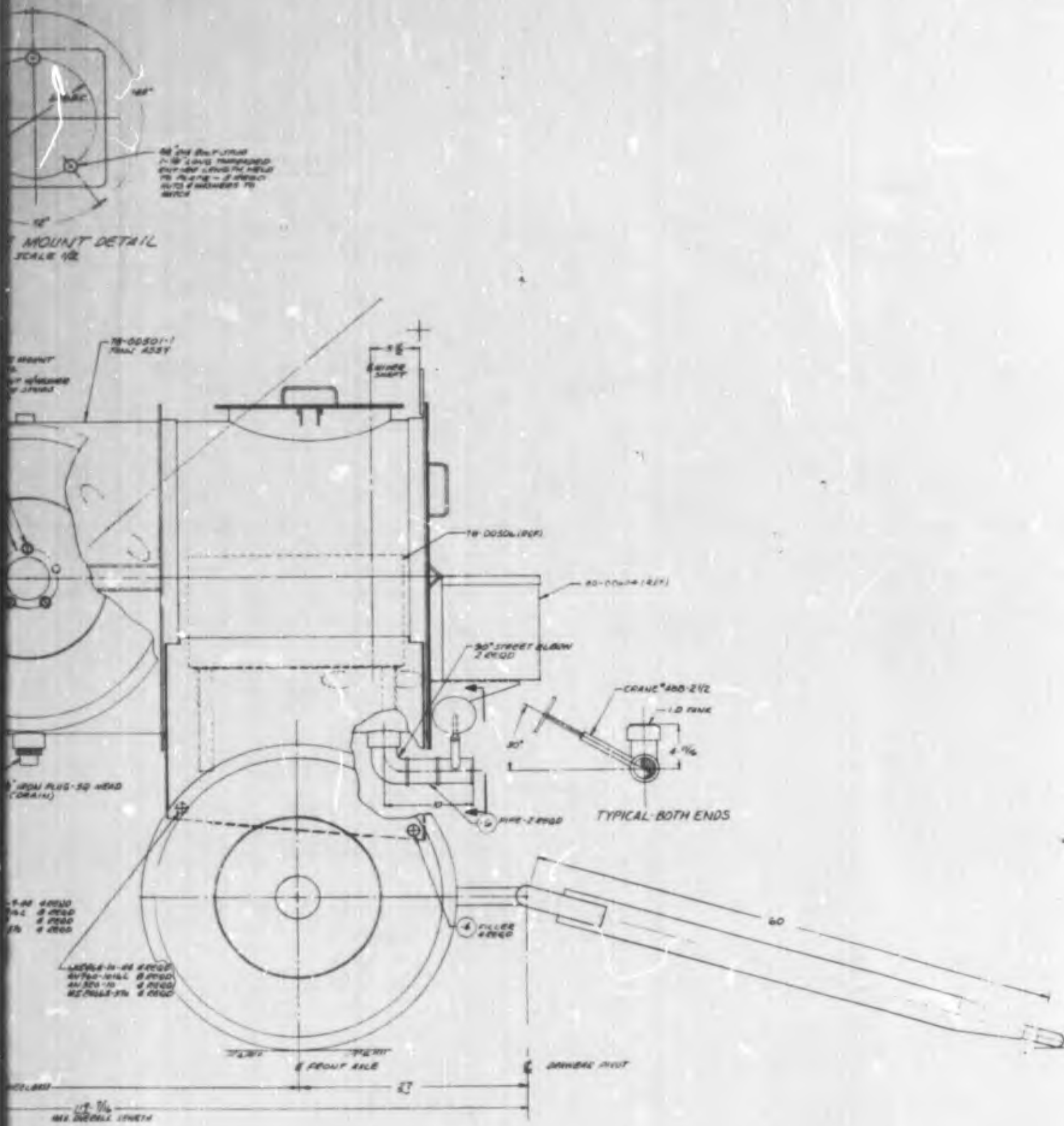
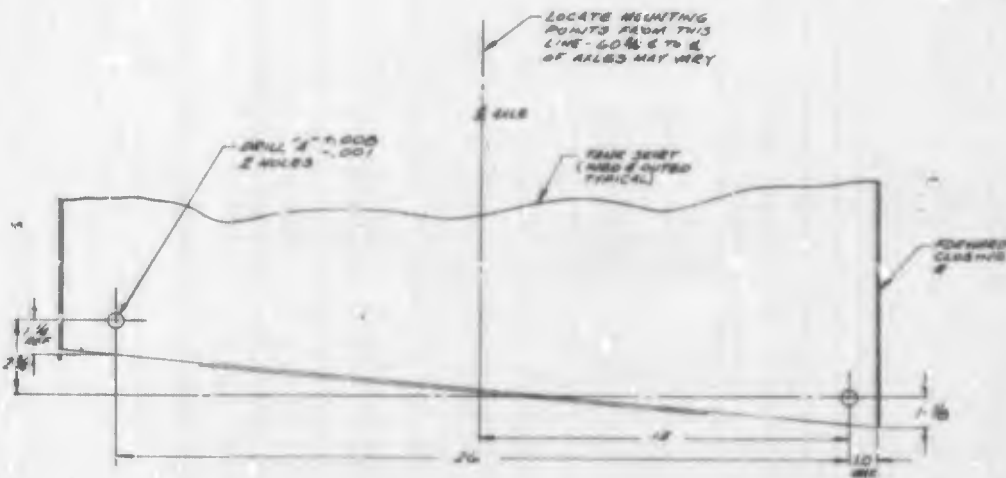


Figure 12. Tank Trailer Assembly Rapid Site (a)

B



- NOTES.
1. MOUNTING TANK TO RUNNING GEAR:
    - A. MOUNTING HOLE LOCATION TO BE DETERMINED ON TANK SHEETS (SEE TANK MOUNTING HOLE LOCATION DETAIL) AFTER TANK ASSY TOLERANCE BUILD-UP HAS BEEN DETERMINED.
    - B. INSTALL SPRING EYES WITH LINK PLATES TO ASSURE FREEDOM OF ROTATION AROUND MOUNTING BOLTS.
    - C. FILLETS MAY BE GRINDING DOWN OR WASHERS MAY BE ADDED AT ALL MOUNTING POINTS TO ASSURE FREEDOM OF ROTATION.
    - D. BOTTOM OF TANK TO BE PARALLEL WITH  $\phi$  OF AXLES AFTER MOUNTING.
  2. RUNNING LIGHTS:
    - A. CONFORMS TO PART 189 W/ L.C.C. SAFETY REGULATIONS.
    - B. SHOP TO PROVIDE CLAMPING DEVICES ON INSTALLATION PER ENGINEERING APPROVAL.
  3. BRAKE LINKAGE:
    - A. SUPPORT HAS BEEN PROVIDED FOR PARKING BRAKE LEVER ATTACHMENT (SEE NADCC DIV 90617).
    - B. SHOP TO PROVIDE BRAKE LINKAGE INSTALLATION PER ENGINEERING APPROVAL.
  4. TOLERANCE ON ALL DIMENSIONS  $\pm 1/16$  EXCEPT AS NOTED.
  5. FINISH COMPLETE ASSY AS FOLLOWS:
    - \* 402 1/2 S-1 CT 1/2 S-1 2 CT
  6. FINISH OF 10-00000-1 TANK TRAILER ASSY REQD.
  7. STAMP NUMERATE AS FOLLOWS:
    - LINE 1: TANK TRAILER ASSEMBLY
    - LINE 2: ITDL RAPID SITE
    - LINE 3: STICK NO. 65C 58
    - LINE 4: PART NO. 70-00000-1
    - LINE 5: CONTRY AT 0000000000
    - LINE 6: SERIAL NO. 1
    - LINE 7: FILL WITH RAPID SITE
    - LINE 8: RESIN ONLY
    - LINE 9: WT. 2250LBS

TANK MOUNTING HOLE LOCATION  
SCALE 1/2

SPRING MOUNT	"A"
REAR	5/16
FRONT	3/8



FILLER DETAIL  
SCALE 1/1

DASH NO	"B"	"C"	"D"
-2	5/16	3/16	1 3/8
-3	1/2	3/16	1 3/8
-4	3/8	3/8	1 1/2

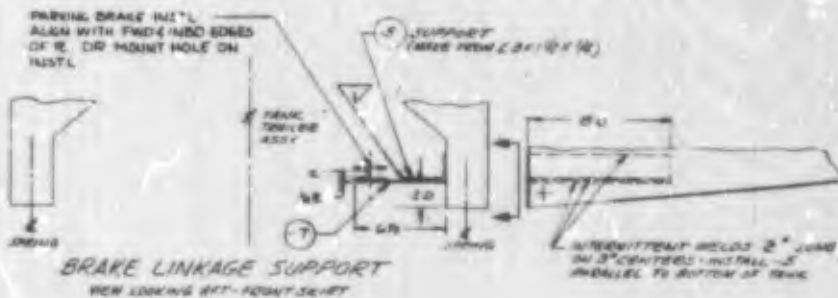


Figure 12. Tank Trailer Assembly Rapid Site (b)

A

NOTES:

1. MOUNTING TANK TO RUNNING GEAR:

- A. MOUNTING HOLE LOCATION TO BE DETERMINED ON TANK SHIRTS (SEE TAN. MOUNTING HOLE LOCATION DETAIL) AFTER TANK ASSY TOLERANCE BUILD-UP HAS BEEN DETERMINED.
  - B. INSTALL SHIRTS WITH LINE PLATES TO ASSURE FREEDOM OF ROTATION ABOUT MOUNTING BOLTS.
  - C. FILLERS MAY BE GROUNDED WITH OR WITHSHIRTS MAY BE ADDED AT ALL MOUNTING POINTS TO ASSURE FREEDOM OF ROTATION.
  - D. BOTTOM OF TANK TO BE PARALLEL WITH  $\phi$  OF AXLES AFTER MOUNTING.
2. RUNNING LIGHTS:
- A. CONFORMS TO PART 135 OF I.C.C. SAFETY REGULATIONS.
  - B. SHOP TO PROVIDE CLAMPING OR WIRES ON INSTALLATION PER ENGINEERING APPROVAL.
3. BRAKE LINKAGE:
- A. SUPPORT HAS BEEN PROVIDED FOR PARKING BRAKE LEVER ATTACHMENT (SEE NADCO DWG #6917).
  - B. SHOP TO PROVIDE BRAKE LINKAGE INSTALLATION PER ENGINEERING APPROVAL.
4. TOLERANCE ON ALL DIMENSIONS  $\pm 1/8$  EXCEPT AS NOTED.
5. FINISH COMPLETE ASSY AS FOLLOWS:  
 #681 #365-1 CT / #366 2 CT
6. FOUR OF 78-00500-1 TANK TRAILER ASSY REQD
7. STAMP NAMEPLATE AS FOLLOWS:
- LINE 1: TANK TRAILER ASSEMBLY  
 LINE 2: VTOL RAPID SITE  
 LINE 3: STOCK NO. 65C 58  
 LINE 4: PART NO. 78-00500-1  
 LINE 5: CONTRACT AFDB(61)306B  
 LINE 6: SERIAL NO. 1  
 LINE 7: FILL WITH RAPID SITE  
 LINE 8: RESIN ONLY  
 LINE 9: WT. 2250LBS

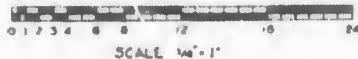
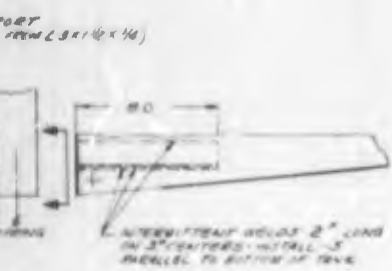
TANK TRAILER DATA:

CAPACITY: 400 GALLONS  
 HEIGHT (LBS EST) NET 2250, PAYLOAD 4800, GROSS 7050  
 GROUND CLEARANCE - 13 1/8 INCHES  
 OVERALL LENGTH - 121 INCHES (DRAWBAR IN VERTICAL POSITION)  
 OVERALL HEIGHT - 78 1/8 INCHES  
 OVERALL WIDTH - 74 1/8 INCHES  
 BRAKES 2 WHEEL ELECTRIC SERVICE BRAKES  
 REAR MANUALLY OPERATED PARKING BRAKES

REV	DESCRIPTION	DATE APPROVED
A	ADDED CATALYST 4 FIBER GLAS CONTAINERS	7/20/65 RJE
B	1. RELOCATED CATALYST CONTAINER 2. CORRECTED RUNNING GEAR 3. CORRECTED HEIGHT 4. CORRECTED NAMEPLATE DATA 5. CORRECTED TIRE MOUNT DETAIL 6. CORRECTED TANK MOUNT PLATE	7/20/65 RJE

SER NO.	STOCK NO.
1	65C 58
2	65C 59
3	65C 60
4	65C 61

- 8	PLATE TIRE MOUNT		
- 7	PLATE BRAKE SUPPORT		
78-00500-1	TANK TRAILER ASSEMBLY		
78-00500-1	FIBERGLAS CONTAINER		
1 6079	PINBLE HOOR	NADCO	PURCHASED WITH RUNNING GEAR
1 CXC3000	NAMEPLATE		
3 4524053R	WASHER		
3 4524053R	WASHER		
3 4524053R	WASHER		
4 4524053R	BOLT		
4 4524053R	BOLT		
4 4524053R	BOLT		
1 3580	SUCRET LIGHTS	DEAL (RALPH CLARK CO.)	PURCHASED BY EO 10032 4 DATED 7-13-65
1 3579	PLUS LIGHTS	DEAL (RALPH CLARK CO.)	
2 1817400R	RUNNING LIGHTS	DEAL (RALPH CLARK CO.)	
2 2 180N	PLUG SO HEAD 5/16"	LEANE (SOUTHLAND SUPPLY CO)	
2 2 180N	90° STREET ELBOW	LEANE (SOUTHLAND SUPPLY CO)	PURCHASED BY EO 10032 4 DATED 7-13-65
2 404 142	VALVE	LEANE (SOUTHLAND SUPPLY CO)	PURCHASED BY EO 10032.12 DATED 7-30-65
1 9724	RUNNING GEAR	NADCO	PURCHASED BY EO 10032.3 DATED 6-29-65
1 78-70500-1	TANK ASSY		PURCHASED BY EO 10032 2 DATED 6-28-65
2 -6	PIPE		PURCHASED BY EO 10032 4 DATED 7-13-65 2 1/2" I.D. 4.5" LONG GALV IRON, 1/4" DIA. NPT THREADS ON EACH END
1 -5	SUPPORT BRK LINKAGE		
4 -4	FILLER		
4 -3	FILLER		
4 -2	FILLER		
1	TANK TRAILER ASSY		
1	PART NO.	ALPHABETIC	VENDOR
1			48 MARKS



B

### 3. Subsystem Description

#### (1) General

The application equipment mounted on the prime mover consists of pumps, control valves, lines, catalyst tank and metering valves, fiberglass application equipment, air compressor and associated power transmission equipment. A control panel for the control and monitoring of the various operations was included (Figure 13). Power for the operation of the various subsystems was provided by the prime mover engine through the vehicle power takeoff, from which it was directed to the air compressor and fluid pumps by an arrangement of shafts, pulleys, belts, and clutches (Figure 14). A subsystem schematic diagram shown in Figure 15 presents power, fluid flow and controls of the truck mounted equipment. A detailed description of the equipment subsystems and their operations is contained in the Preliminary Equipment Operation Instructions (Reference 3).

#### (2) Power Transmission Requirements

The basic power transmission is shown schematically in Figure 14. The truck engine supplies power through its transmission and transfer case to a power takeoff (PTO) unit which in turn supplies power through a series of belts to drive the compressor jack shaft and the two resin pump jack shaft drives. The compressor is driven at a nominal 870 rpm and requires approximately 20 hp to produce system air flow requirements. Power delivered to the fluid by each resin pump at a 5 gpm flow rate, 70°F resin temperature, was calculated to be 0.91 hp per pump. Assuming a 50 percent pump efficiency and a 50 percent drive efficiency, the power input to each pump system is approximately 3.65 horsepower. The total power requirements is a nominal 28.3 horsepower. Friction slip clutches were incorporated in each pump drive to protect the transmission and the pumps from the results of physical jamming of either pump. Three pump speeds producing nominally 2 gpm, 5 gpm, or 7 gpm flow rates may be selected through an idler arrangement that engages and disengages different ratio belt drives.

#### (3) Compressed Air Supply

A two-stage air compressor with a rated output of 81 cfm at 100 psi is provided to supply the resin pole gun nozzles, the fiberglass dispensing units, and for pressurization of the catalyst supply tank and the solvent flushing system.

#### (4) Catalyst Injection System

The catalyst injection system delivers a metered amount of catalyst to the resin spray nozzle where it is mixed with the resin. The supply tank is pressurized at 80 psi. Catalyst is allowed to pass through a needle valve and a flow meter and is then introduced into an air supply line where the catalyst is transported to the resin pole gun nozzle. Mixing of catalyst and resin is performed by the "tuned" nozzle

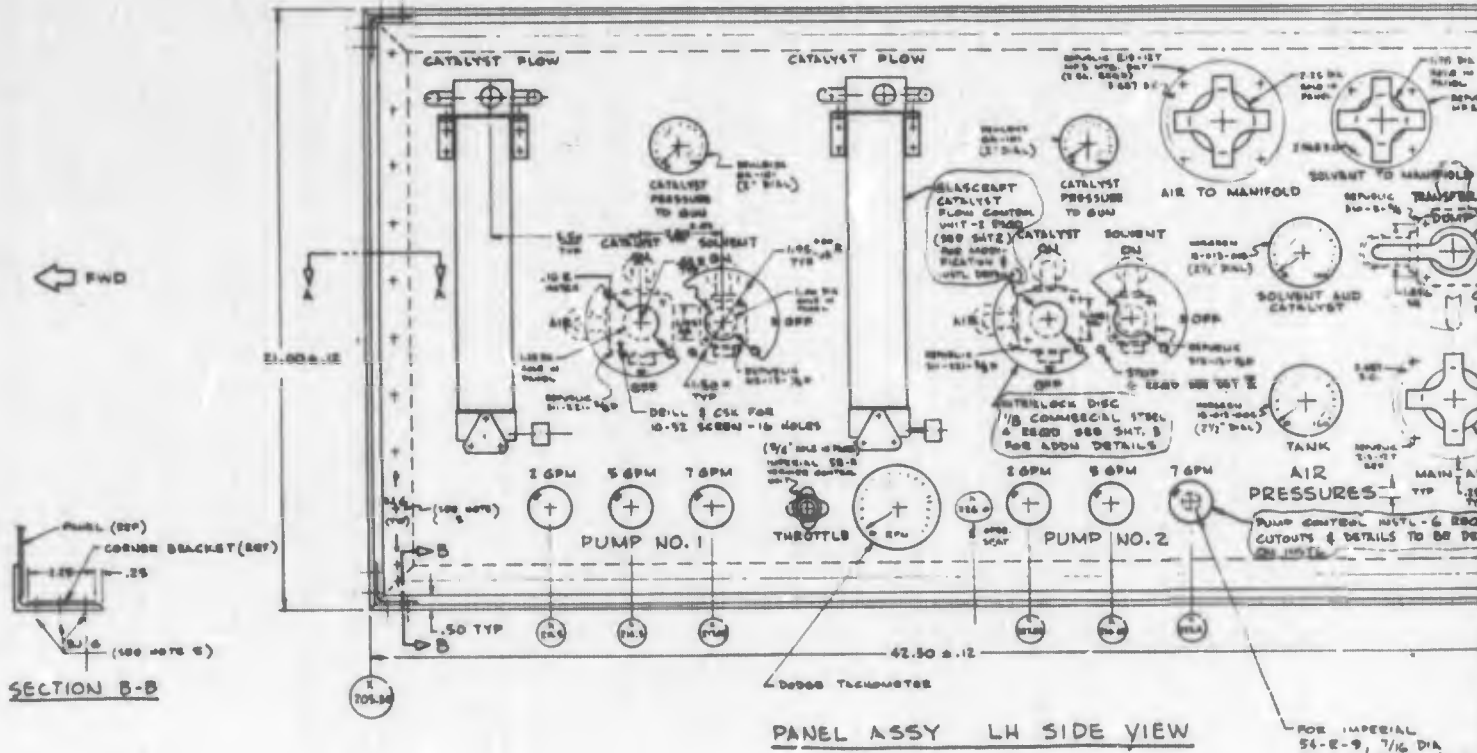
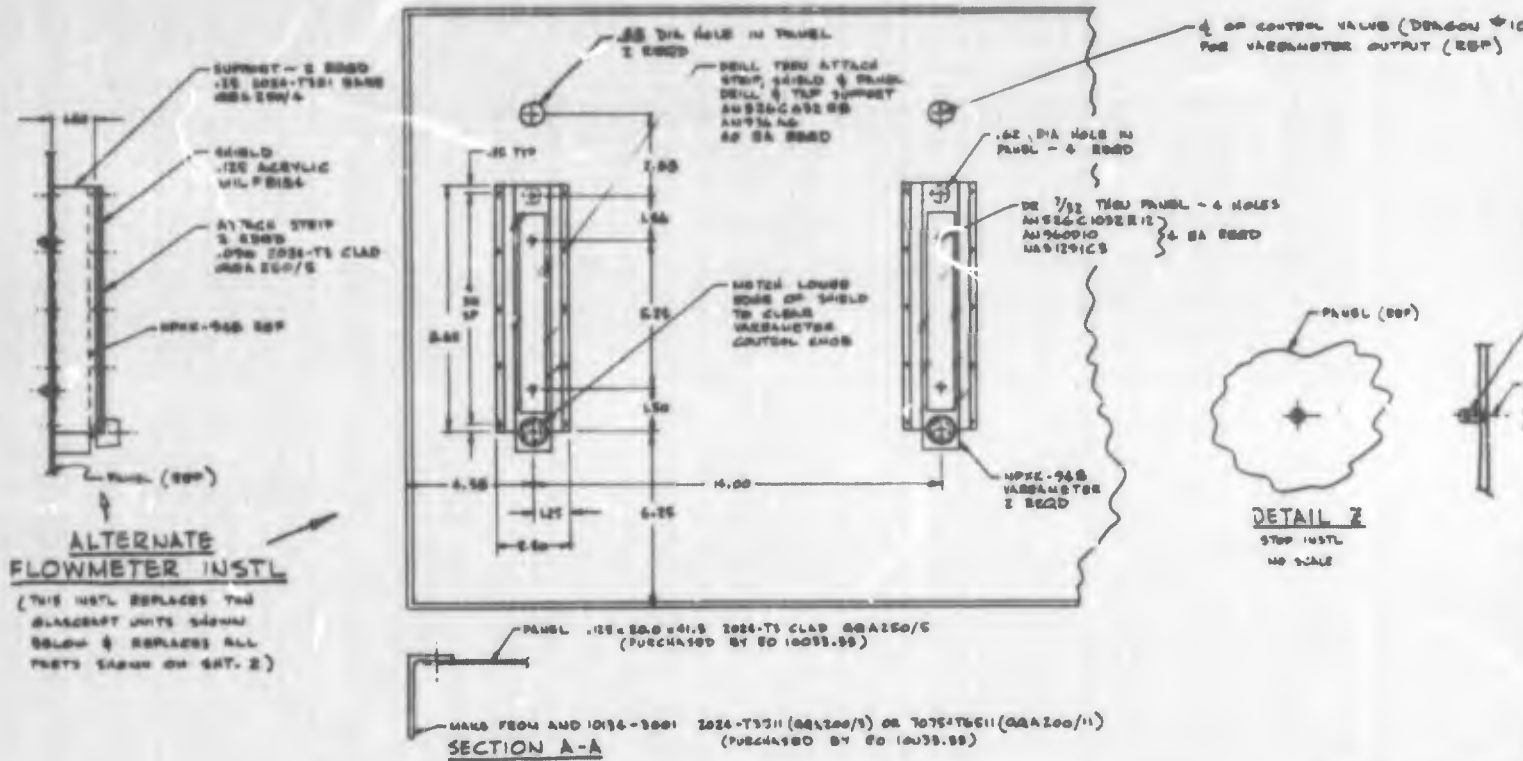


Figure 13. Operator's Control Panel Assembly

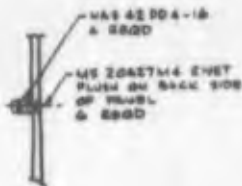
1/4" CO-TERL VALVE (DORSON #1040577)  
FOR BAROMETRIC OUTPUT (ESP)

WELD IN  
SSGD

TRIM PANEL - 4 HOLES  
CLOSED  
1/16" DIA  
1/16" DIA



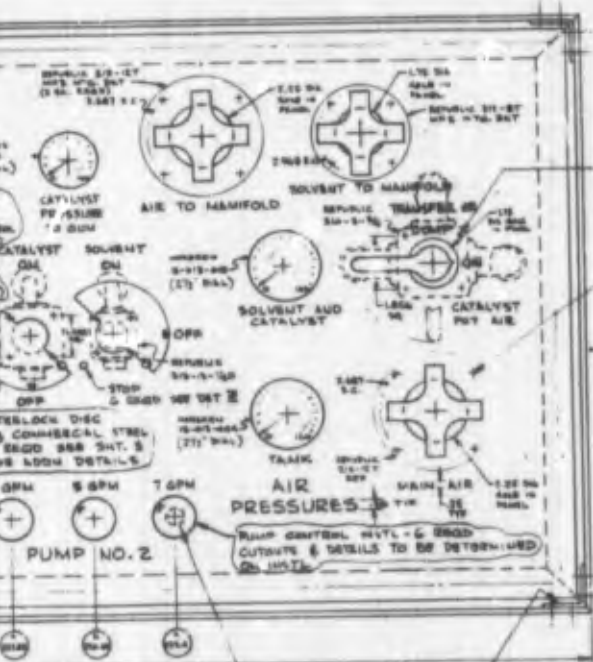
DETAIL Z  
STEP INSTL  
NO SCALE



WAS 2204-16  
& SSGD

MS 20ASTM4 ENVT  
PLUG ON BACK SIDE  
OF PANEL  
& SSGD

ZEV	
A	ADDED ALTERNATE FLOWMETER INSTL
B	ADDED CONTROL VALVE & PANEL HOLE FOR ALTERNATE FLOWMETER
C	ADDED HOLES FOR THROTTLE CONTROL & PUMP CLUTCH CONTROLS. REVISED ENGRAVING FOR CATALYST POT AIR VALVE



DRILL & CSC  
FOR 1/2"-1/8"  
PLUS SCREW  
& NUTS

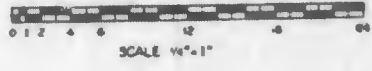
DRILL TO MATCH  
INSTL DATE ON  
ALL 1/2" 3/8" 1/4"  
VALVES. INSTL  
VALVE WITH  
HOW PROV'D  
WITH VALVE

AIR PRESSURES  
PUMP CONTROL NYTL - 6 SSGD  
OUTLINE & DETAILS TO BE DETERMINED  
ON INSTL

CORNER BRACKET - 4 SSGD  
WELD FROM AND 10135-1605  
1024-79511 (QGA 300/1) OR  
1024-79511 (QGA 300/1)

FOR IMPERIAL  
51-E-8, 7/16" DIA  
HOLE IN PANEL (719 & 716)

- NOTE:**
1. BREAK SHARP EDGES
  2. FABRICATE ONE PANEL ASSY
  3. ENGRAVE .25 & .30 HIGH LETTERS. FILL WITH BLACK ENAMEL
  4. LOCATE COMPONENTS APPROX. AS SHOWN. NON-DIMENSIONED FEATURES MAY BE SCALED
  5. SPACE RIVETS TO SUIT
  6. FLUID FITTINGS SHOWN FOR CLEARANCE ESP ONLY. FOR ACTUAL FITTINGS, SEE 18-00617
  7. FINISH PANEL ASSY AS FOLLOWS PRIOR TO INSTALLING COMPONENTS:
    - A. 04
    - B. 040/1CT
    - C. 067/2CTS
  8. NPK-948 BAROMETER ORDERED BY SO 10033.45



150

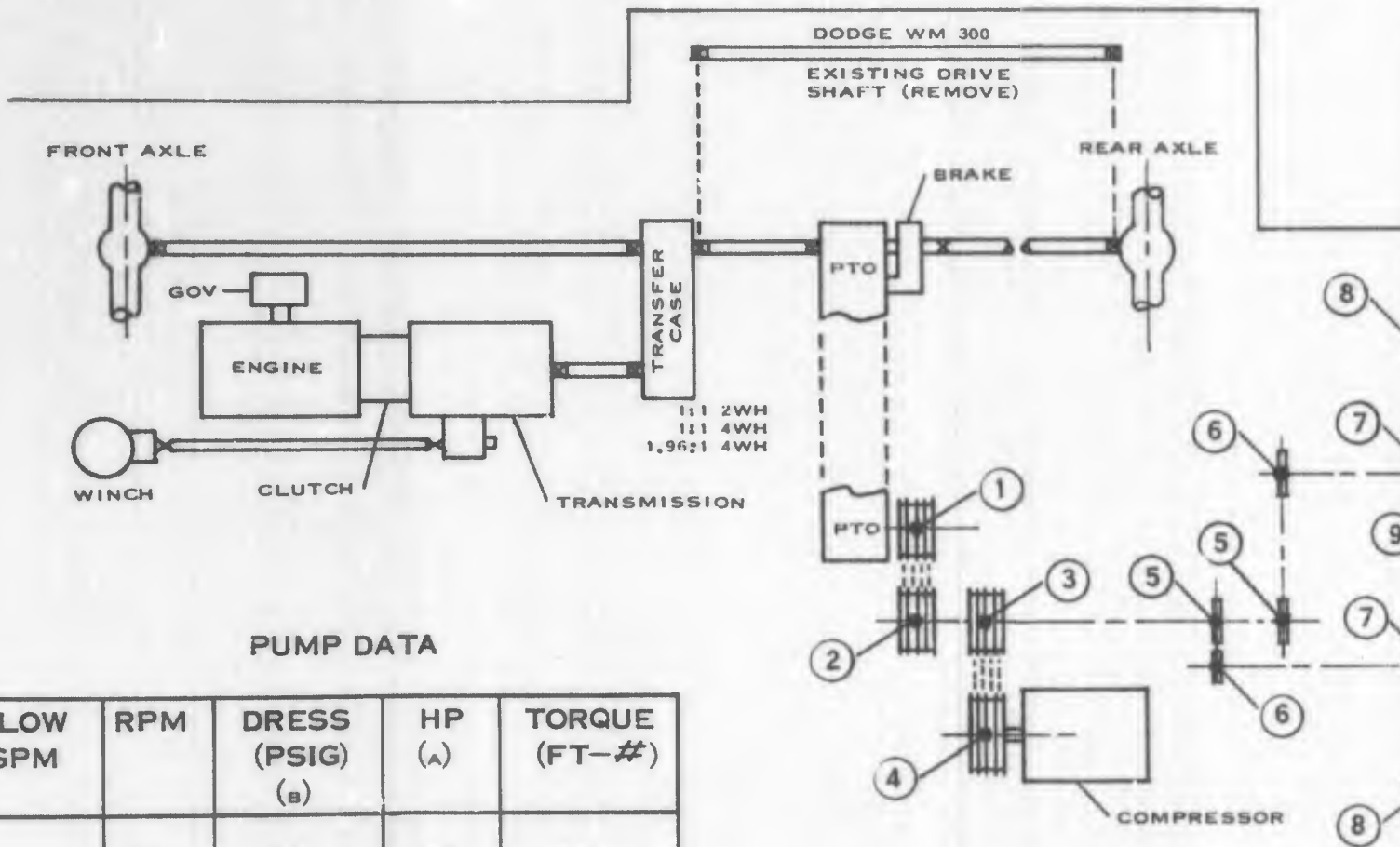
160

150

B

1. 1500 RPM; 23.68 HP; 7.9" O.D. ,4 GROOVE "C" SHEAVE (WITH PTO).
2. 1120 RPM; 23.68 HP; 10.5" P.D. "C" SHEAVE, 4 GROOVE.
3. 1120 RPM; 23.68 HP; 18.4" P.D. "B" SHEAVE, 5 GROOVE.
4. 870 RPM; 20.00 RP; 23.5"O.D. 5 GROOVE "B" SHEAVE (WITH COMPR.).
5. 1120 RPM; 1.84 HP; 2.65" 3V SHEAVE, 4 GROOVE.
6. 275 RPM; 1.84 HP; 10.60" 3V SHEAVE, 4 GROOVE.
7. 275 RPM; 1.84 HP; 5.00" 3V SHEAVE, 3 GROOVE.

8. 121 RPM; 1.84
9. 275 RPM; 1.84
10. 275 RPM; 1.84
11. 400 RPM; 1.84
12. THREE POSSIBLE  
121 RPM AND  
.378 RPM AND
13. SEE PUMP DA



PUMP DATA

FLOW (GPM)	RPM	DRESS (PSIG) (a)	HP (A)	TORQUE (FT-#)
	121	75 (EST)	0.2	8.7
5	275	94	0.9	17.2
7	378	120	1.4	19.5
BYPASS	378	175	1.75	24.3

A

8. 121 RPM; 1.84 HP; 10.60" 3V SHEAVE, 3 GROOVE.
9. 275 RPM; 1.84 HP; 4.75" 3V SHEAVE, 4 GROOVE.
10. 275 RPM; 1.84 HP; 6.50" 3V SHEAVE, 3 GROOVE.
11. 400 RPM; 1.84 HP; 4.75" 3V SHEAVE, 3 GROOVE.
12. THREE POSSIBLE CONDITIONS AS FOLLOWS:  
 121 RPM AND 1.84 HP, 275 RPM AND 1.84 HP  
 .378 RPM AND 1.84 HP.
13. SEE PUMP DATA BELOW.

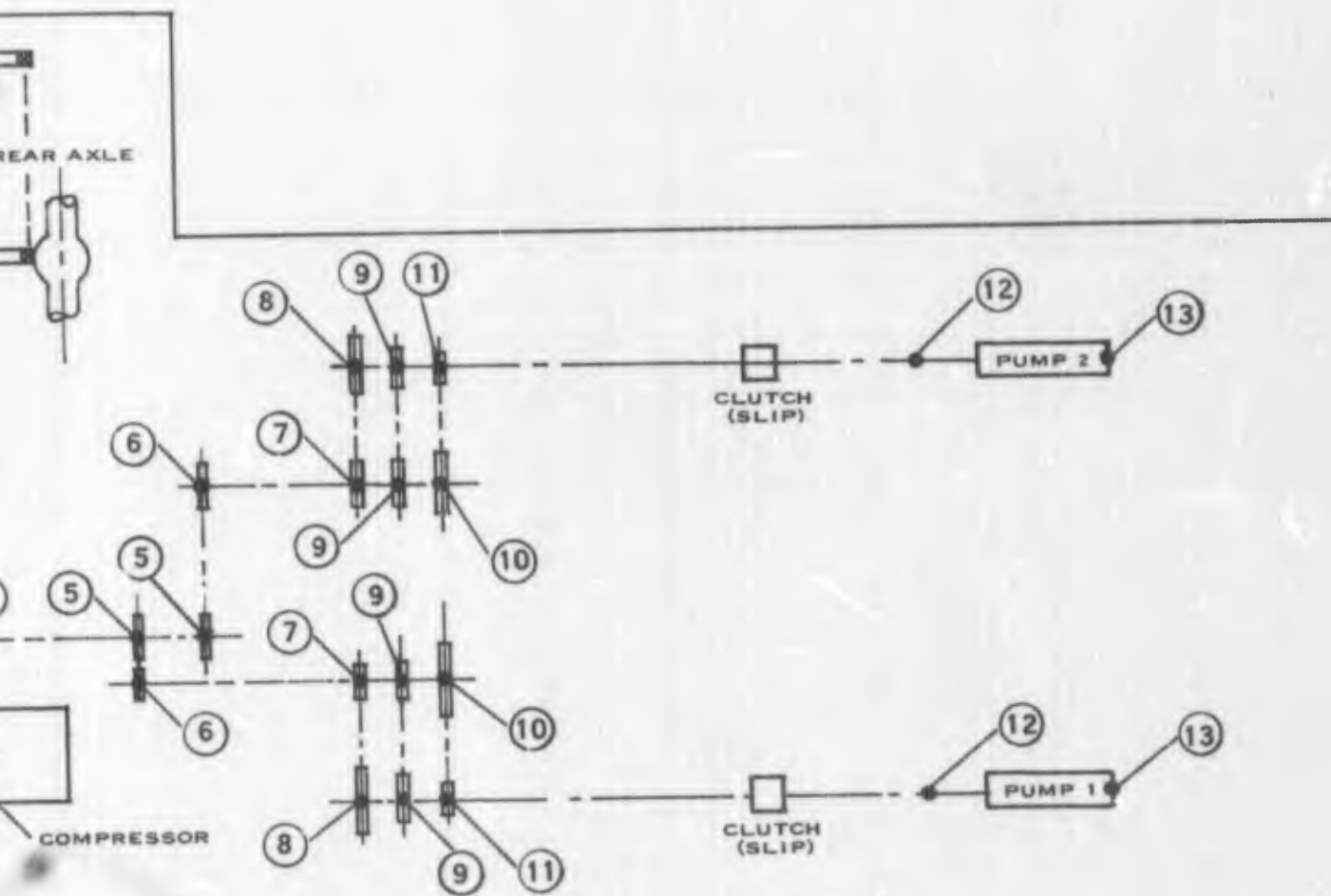


Figure 14. Power Transfer Schematic

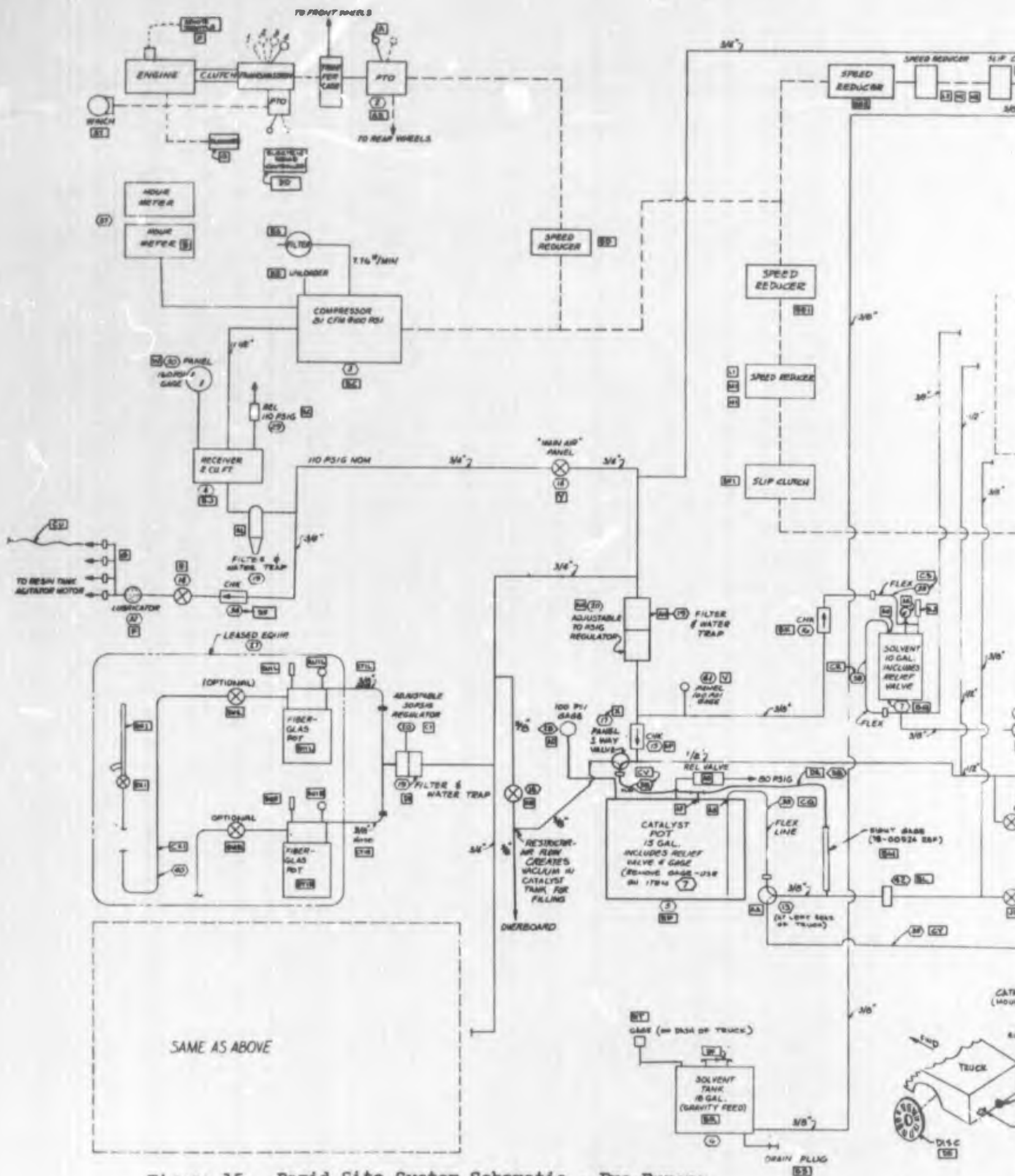
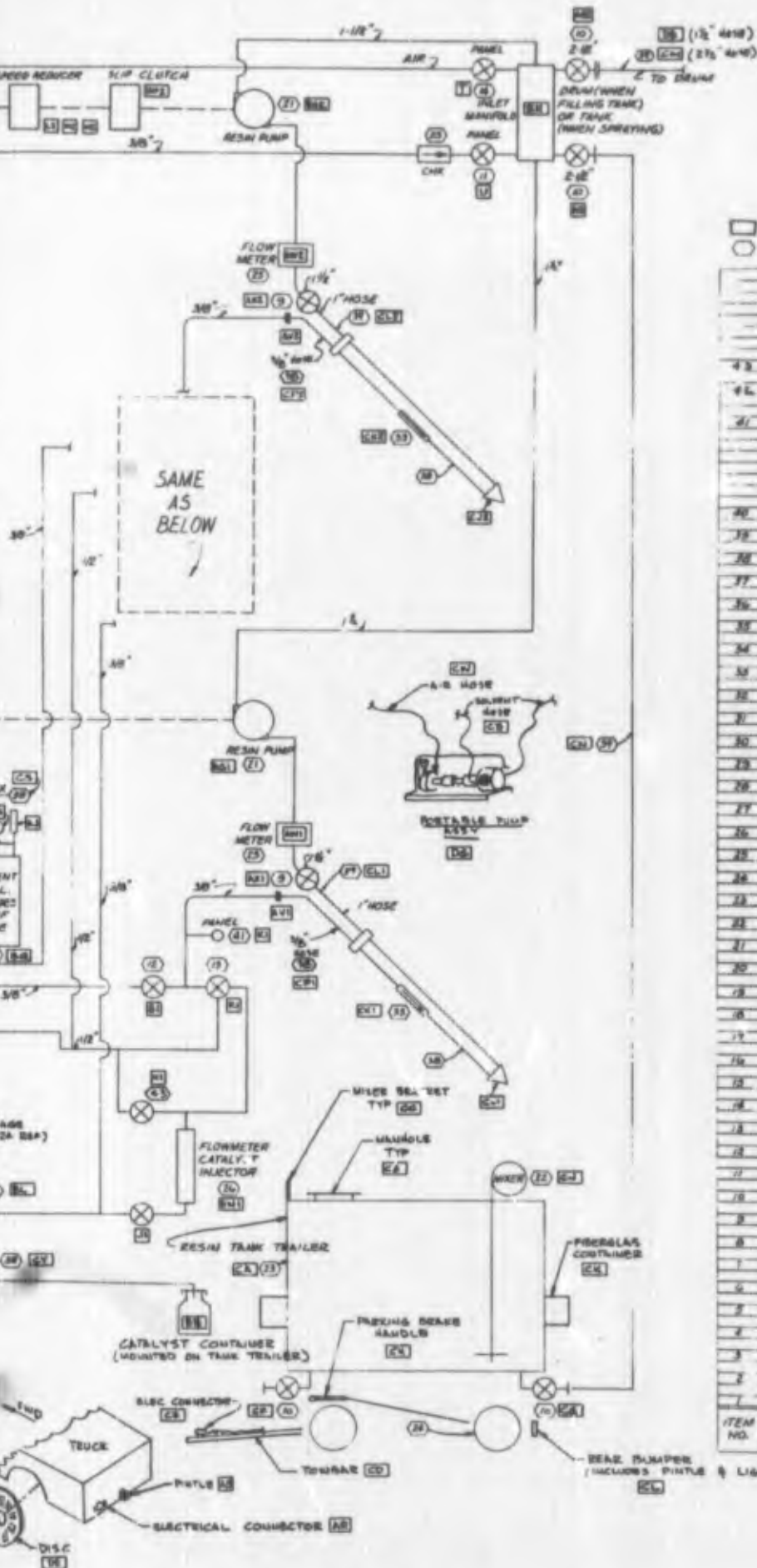


Figure 15. Rapid Site System Schematic - Pre-Europe

A



LETTERS IN BOX REFER TO ITEM CALLOUTS IN DRS MANUAL 7  
 NOT INDICATED ON 78-00509  
 INDICATES ITEM NO.

THIS COLUMN WILL NOT BE UPDATED BY ENG

ITEM NO.	QTY	NOMENCLATURE	VENDOR PART NO.	VENDOR	REQD BY	DATE	ANTIC. ACTING	RECEIVED	W/OCCASION
43	3	HEATING WIRE 120V 8FT		SHAW-WALKER WIRE	7-15-65				1 SHAW
44	2	CATALYST INJECTOR 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				2 SHAW
45	2	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				2 SHAW
46	1	CATALYST INJECTOR 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
47	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
48	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
49	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
50	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
51	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
52	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
53	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
54	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
55	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
56	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
57	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
58	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
59	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
60	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
61	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
62	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
63	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
64	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
65	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
66	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
67	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
68	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
69	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
70	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
71	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
72	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
73	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
74	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
75	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
76	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
77	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
78	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
79	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
80	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
81	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
82	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
83	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
84	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
85	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
86	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
87	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
88	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
89	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
90	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
91	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
92	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
93	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
94	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
95	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
96	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
97	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
98	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
99	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW
100	1	RESIN PUMP 1/2" x 1/2" x 1/2"		SHAW-WALKER	7-15-65				1 SHAW

B

chamber before being dispensed onto the ground in a spray pattern. A dual system is used with separate flow controls to each resin spray system.

#### (5) Resin Pumping System

This equipment provides two independent spray units each supplied by an internal gear pump rated at 5 gpm at a pump discharge pressure of 160 psi. Resin is pumped through a hose to the pole gun fitted with an internal air mixing nozzle. Appropriate shutoff valves, relief valves, and flow meters are used to control pressure and flow.

The pole gun is shown in Figures 16 and 17. This unit, designed by LTV, is similar to commercial guns used for spraying gunite, but modified in two ways. First, the catalyst-air line is inserted from the rear of the gun rather than from the orifice end. This simplifies disassembly and cleaning. Secondly, the body length is adjustable, permitting the operator to vary the position of the orifice relative to the catalyst-air line exit. This permitted "tuning" of the nozzle during operation to suit resin flow rate, viscosity, and other factors which "tune". (The "tuned" nozzle effect is discussed in Reference 2.)

#### (6) Fiberglass Dispensing System

Fiberglass is dispensed by two operators with continuous roving feed units. These glass dispensing units are pressurized supply pots containing the continuous fiberglass roving. The fiberglass is transported through a hose and blown onto the surface by air pressure.

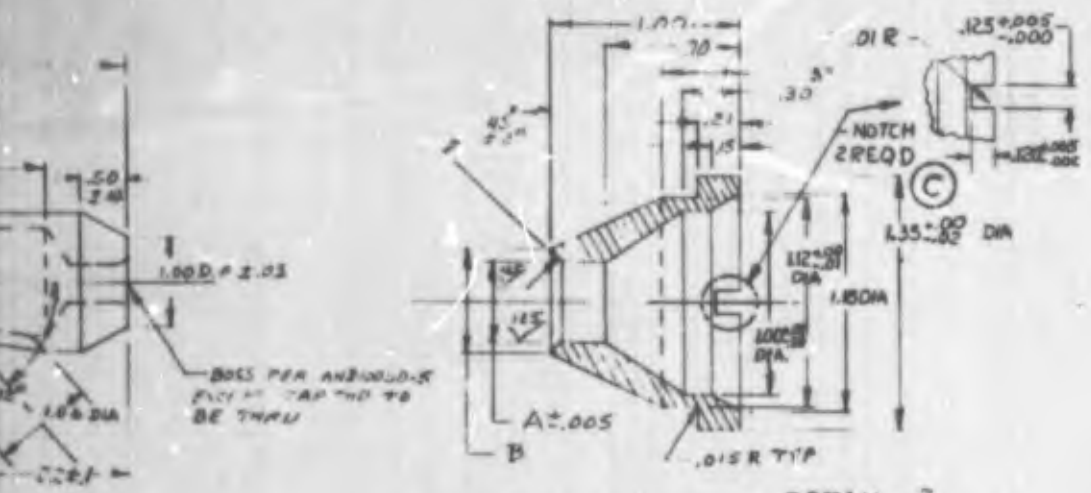
#### d. Equipment Checkout and Operation

Detailed equipment checkout and operating instructions were provided in Reference (3), Preliminary Equipment Operation Instructions.

### 4. POST-EUROPE MODIFICATIONS

During the fabrication of landing sites in England and Germany, several deficiencies and operational problems were observed in the Phase I application equipment, as described in Section V of this report. Modifications to correct all of these problems were considered too costly, but many of them were incorporated during the latter part of the Phase I program. In general, these modifications were made either to correct performance deficiencies or to improve operational techniques. Although the application equipment could have been used for further site preparation without modification, the changes were made to expedite construction of sites considerably larger than those originally anticipated for the Rapid Site Phase I program. In addition, several large sites to be laid during Phase II were added to program plans during Phase I, and the improvements to the equipment were felt to be necessary for adequate support of these sites.





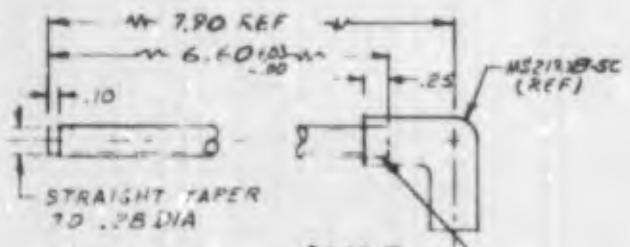
QTY	NOZZLE	A DIA	B DIA
1	-3 A	.375	.57
1	-3 B	.250	.57

EXT RADII .03R

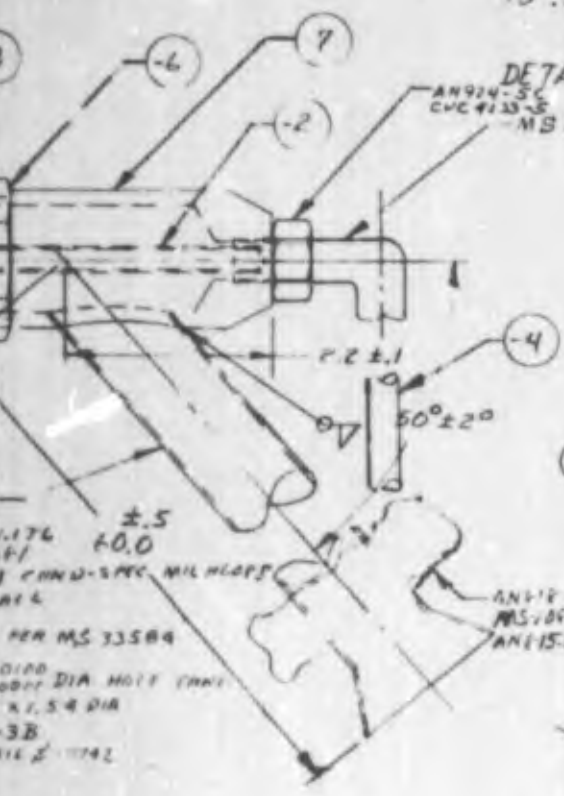
DETAIL - 3  
 NOZZLE  
 MTL CRF5 303  
 MILS 9720 COND 'A'  
 1/8 DIA RD EAM

2A2250 1/8 DIA 40D  
 1/8 DIA RD EAM

AN 915-SC  
 MS 20819-SC  
 AN 816-6-6D  
 AN 804265  
 FLARE FOR  
 MS 33584  
 NAS 1595-5 (A)



DETAIL - 2  
 BRAZE TO MS 2190B-SC  
 MAKE FROM CRF5 304 T1A1-404  
 5/16 OD TUBE .035 WALL



AN 924-SC  
 NAS 1595-5  
 MS 21922-5C  
 1 MS 21921-5C  
 AN 804265  
 AN 816-6-6D  
 AN 815-16D  
 MS 20819-16  
 MS 20819-5C  
 AN 818-16C  
 AN 818-5C

(A2)  
 PURCHASED BY EO 10033,32

QTY REQ	ZONE	CODE	ICENT	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTE	UNIT WT
1				MS 2190B-SC	FLOW 90°		
1				CVC 4233-5	GASKET		
1				-10	HAND GRID (MAHOGANY)		
1				-9	COLLAR	FI	
1				-8	TUNER	~	
1				-7	HOUSING	FI	
1				-6	JAM NUT	~	
1				-5	TUBE	FI	
1				-4	TUBE	FI	
1				-3A,B,C	NOZZLE	~	
1				-2	CATALYST TUBE	~	
1				-1	NOZZLE ASSY	~	

LIST OF MATERIAL

B

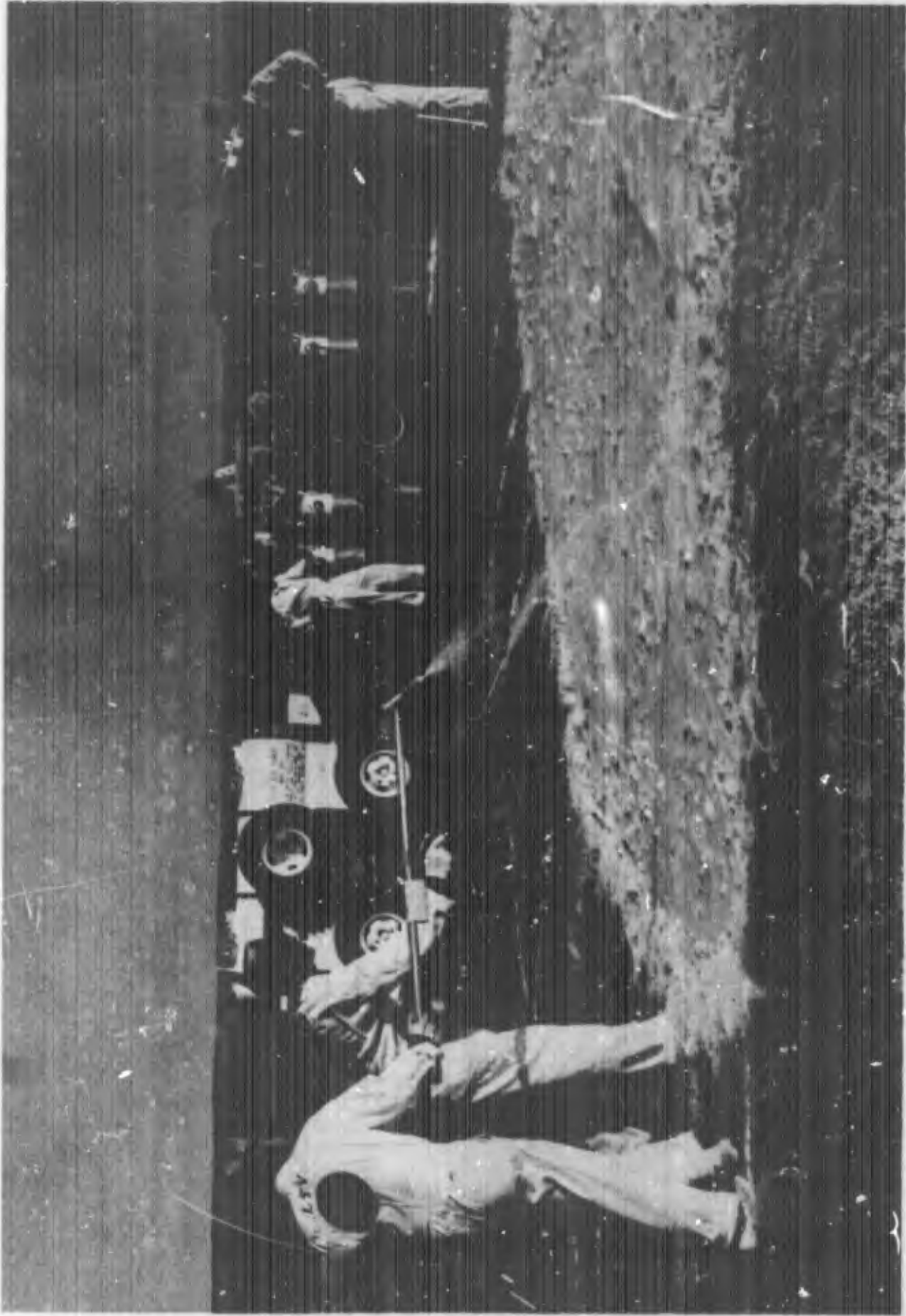


Figure 17. LTV Pole Gun, Pre-Europe

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The following list describes the post-Europe modifications in summary form. Details of each modification are presented in subsequent paragraphs.

Resin Pump Drive System Improvement - Provides infinitely variable resin pump speed between 2 and 7 gpm, improved speed control, more reliable operation. For details, see paragraph a, page 88.

Increased Diameter Resin Lines and Spray Hoses - Permits higher flow rates in resin system at low ambient temperatures. Simplifies suction plumbing. Permits use of longer spray hoses for larger sites. Modified hose storage rack to accommodate larger hoses. For details, see paragraph b, page 97.

Quick Acting Resin Shutoff Valves - Provides means of shutting off resin flow from prime mover through control action at control panel. For details, see paragraph c, page 103.

Miscellaneous Prime Mover Modifications - Several modifications to improve operational characteristics on fluid system, glass system, intercom, and soil disc. For details, see paragraph d, page 106.

Improved Pole Gun - Two pole gun configurations, used in low or high ambient temperatures, provide improved turing, reduced operator fatigue, and greater flexibility of operation. Also usable with unfilled resins. For details, see paragraph e, page 110.

High Pressure, Large Capacity Glass Pot - Provides improved reliability operation. Also permits use of larger glass rolls, reducing time and manpower required for refill. (Design completed during Phase I, but hardware not to be available until Phase II.) For details, see paragraph f, page 115.

Tank Trailer Improvement - Includes addition of several storage boxes; incorporation of provisions for hoisting, fork lifting, and tiedown; front spring modification to improve stiffness; correction of electric brake malfunction; and fabrication of metal shipping skids for air shipment. For details, see paragraph g, page 120.

Portable Resin Transfer Pump - Design and fabrication of 27 gpm trailer mounted pump, transmission and gasoline engine provides separate equipment for transfer of resin from shipping containers to tank trailers. Permits refill operations while prime mover is being used for site application on sites larger than 15,000 pounds. Also available for subsystem tests and evaluation during Phase II. For details, see paragraph h, page 127.

Mover, Roving Fiberglass Dispenser - Provides means of transporting and applying woven roving fiberglass from rolls. Required for site applications using unfilled resins. For details, see paragraph i, page 129.

Hose Support Boom - To be attached to prime mover, provides support for resin hoses, reducing manpower requirements and operator fatigue. (Boom and test stand designed and fabricated during Phase I for test during Phase II.) For details, see paragraph j, page 132.

Miscellaneous Equipment - For details, see paragraph k, page 135.

a. Resin Pump Drive System Improvement

Careful analysis of operational problems encountered in the original resin pump drive system was conducted before a new drive system was proposed. The cost of redesign, component prices, and component availability were investigated to obtain an optimum system within the confines imposed by the prime mover. Downtime to install the new system was held to a minimum, compatible with its impending field use in the Phase I schedule. The system modification, therefore, was so designed that approximately 50% of the fabrication work could be accomplished before disassembly was started on the pre-Europe installation in the prime mover.

The following problem areas were reviewed and considered for the redesign:

- Pump speed indicator
- Variable pump speed control
- Increase of resin system pressure to 200 psi
- Positive pump "stop-start" capabilities
- Increase discharge line size to reduce line loss. (Discussed in detail in paragraph b, page 97.
- Increase pump rpm.
- Increase resin flow rate
- More rapid and corrective control of entire resin system.

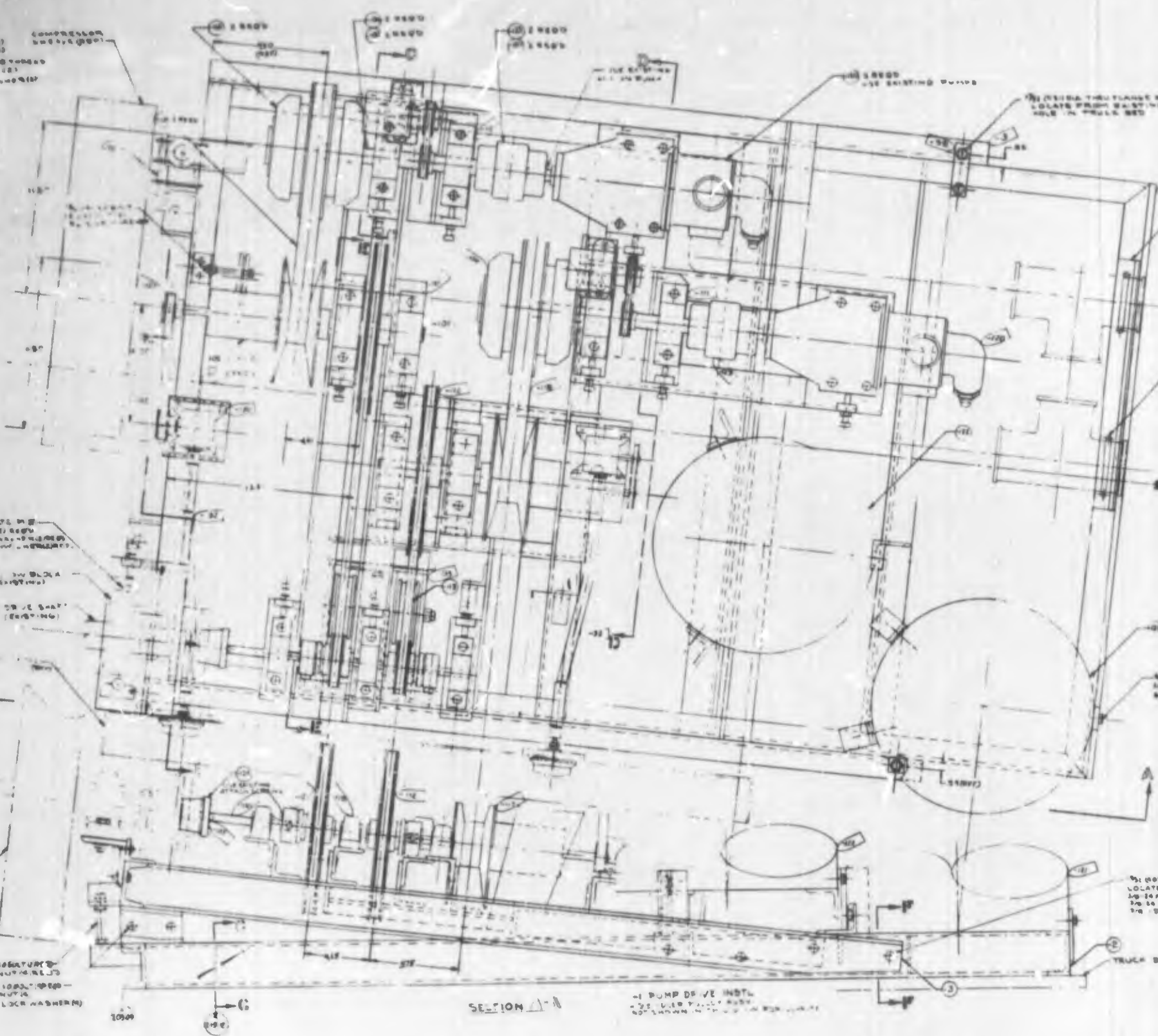
Figures 18, 19, and 20 show details of the post-Europe resin pump drive system. This system replaced in its entirety that part of the pre-Europe system behind the air compressor. The new assembly was joined to the drive jackshaft by an applicable coupling. For assembly purposes jack pads were provided on the frame assembly for vertical adjustments. Lateral movement was accomplished by loosening the U-bolt tiedowns. In this manner, no part of the PTO, main drive jackshaft, or air compressor had to be shifted or disturbed to adapt to the new pump system.

Figure 21 schematically defines shaft number II which drives the two air clutch drive mechanisms. To properly balance the system so that maximum rpm from the main drive could be reduced, the single 'V' belt

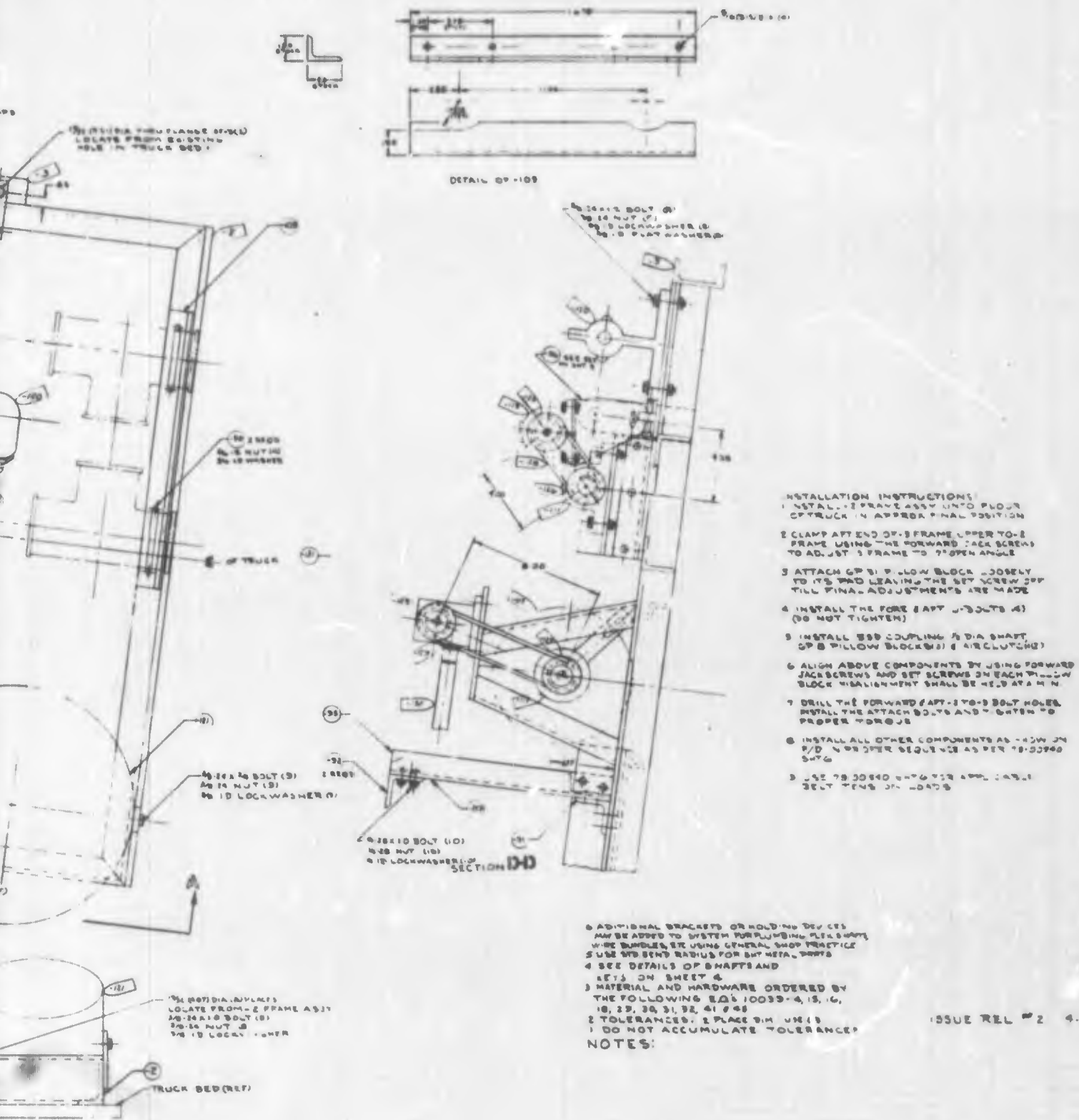


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B



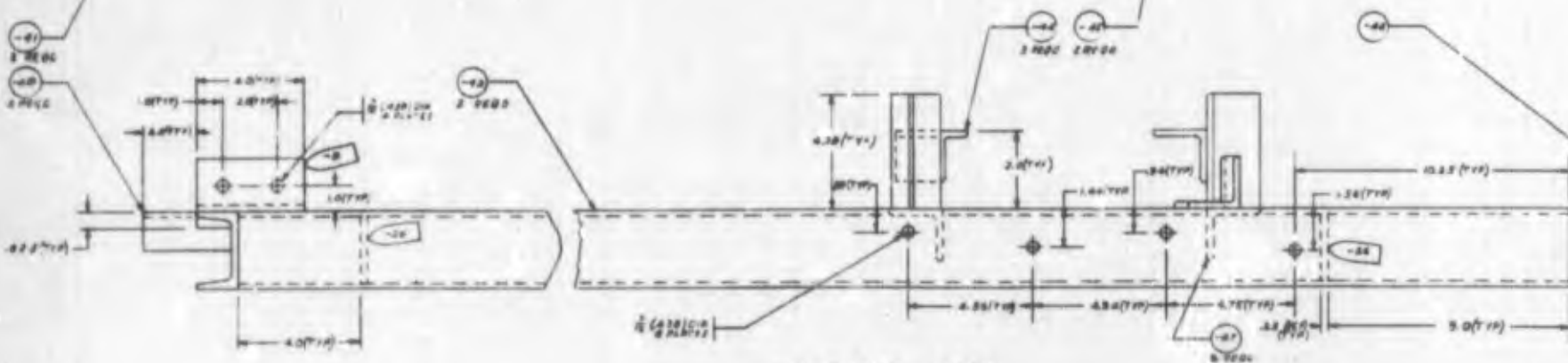
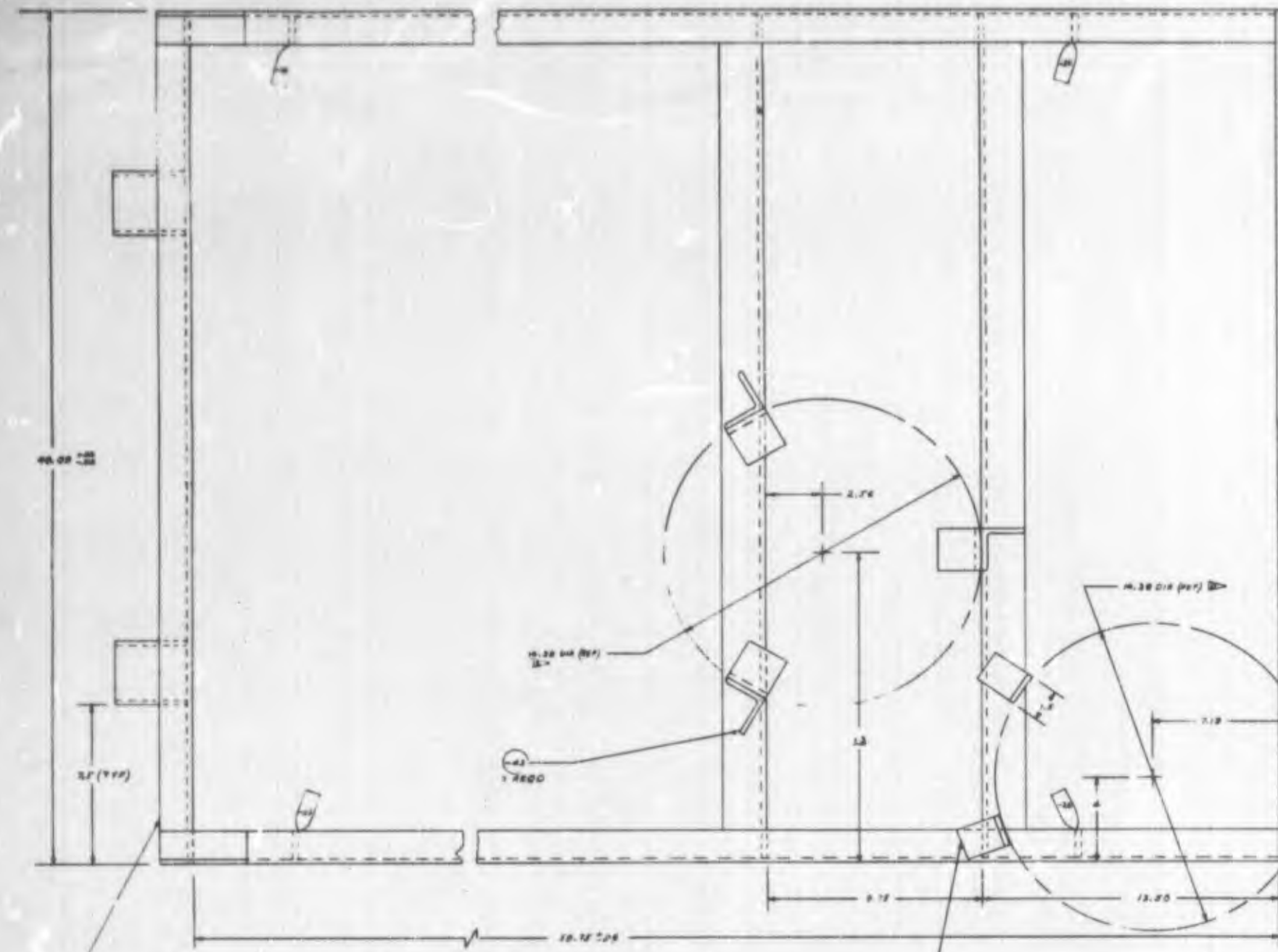
- INSTALLATION INSTRUCTIONS**
1. INSTALL 2 FRAME ASSEMBLY INTO FLOOR OF TRUCK IN APPROXIMATE FINAL POSITION.
  2. CLAMP ONE END OF 2 FRAME UPPER TO 2 FRAME USING THE FORWARD JACK SCREWS TO ADJUST 2 FRAME TO 7° OPEN ANGLE.
  3. ATTACH GP 31 P. FLOW BLOCK LOOSELY TO ITS SHAFT LEAVING THE SET SCREW OFF TO ADJUST 2 FRAME TO 7° OPEN ANGLE.
  4. INSTALL THE FIVE (5) 1/2" BOLTS (4) (DO NOT TIGHTEN).
  5. INSTALL 500 COUPLING 1/2" DIA SHAFT GP 31 P. FLOW BLOCKS (1 AIR CLUTCH).
  6. ALIGN ABOVE COMPONENTS BY USING FORWARD JACK SCREWS AND SET SCREWS ON EACH P. FLOW BLOCK. ALIGNMENT SHALL BE HELD AT 1/4" IN.
  7. DRILL THE FORWARD (AFT) 1/2" DIA BOLT HOLES. INSTALL THE ATTACH BOLTS AND TIGHTEN TO PROPER TORQUE.
  8. INSTALL ALL OTHER COMPONENTS AS SHOWN ON P/D IN PROPER SEQUENCE AS PER 78-30340 SUTG.
  9. USE 78-30340 SUTG FOR APPROXIMATE BELT TENS. ON LOADS.

- NOTES:**
1. ADDITIONAL BRACKETS OR HOLDING DEVICES MAY BE ADDED TO SYSTEM FOR HOLDING P. FLOW BLOCKS TOGETHER. USE GENERAL SHOP PRACTICE.
  2. USE THE BENT RADIUS FOR SHFT METAL PARTS.
  3. SEE DETAILS OF SHAFTS AND SETS ON SHEET 4.
  4. MATERIAL AND HARDWARE ORDERED BY THE FOLLOWING BDL 10033-4, 15, 16, 18, 23, 30, 31, 32, 41 & 42.
  5. 2 TOLERANCED. 1 PLACE DIM. UNLESS DO NOT ACCUMULATE TOLERANCE.

ISSUE REL # 2 4-27-66

Figure 18. Resin Pump Drive (b)

C



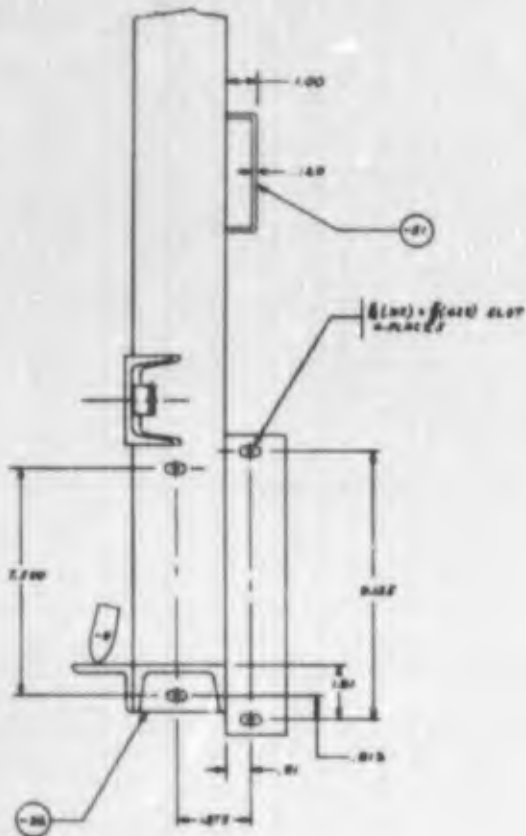
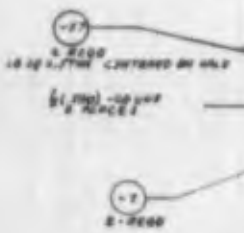
-2 FRAME ASSY

A

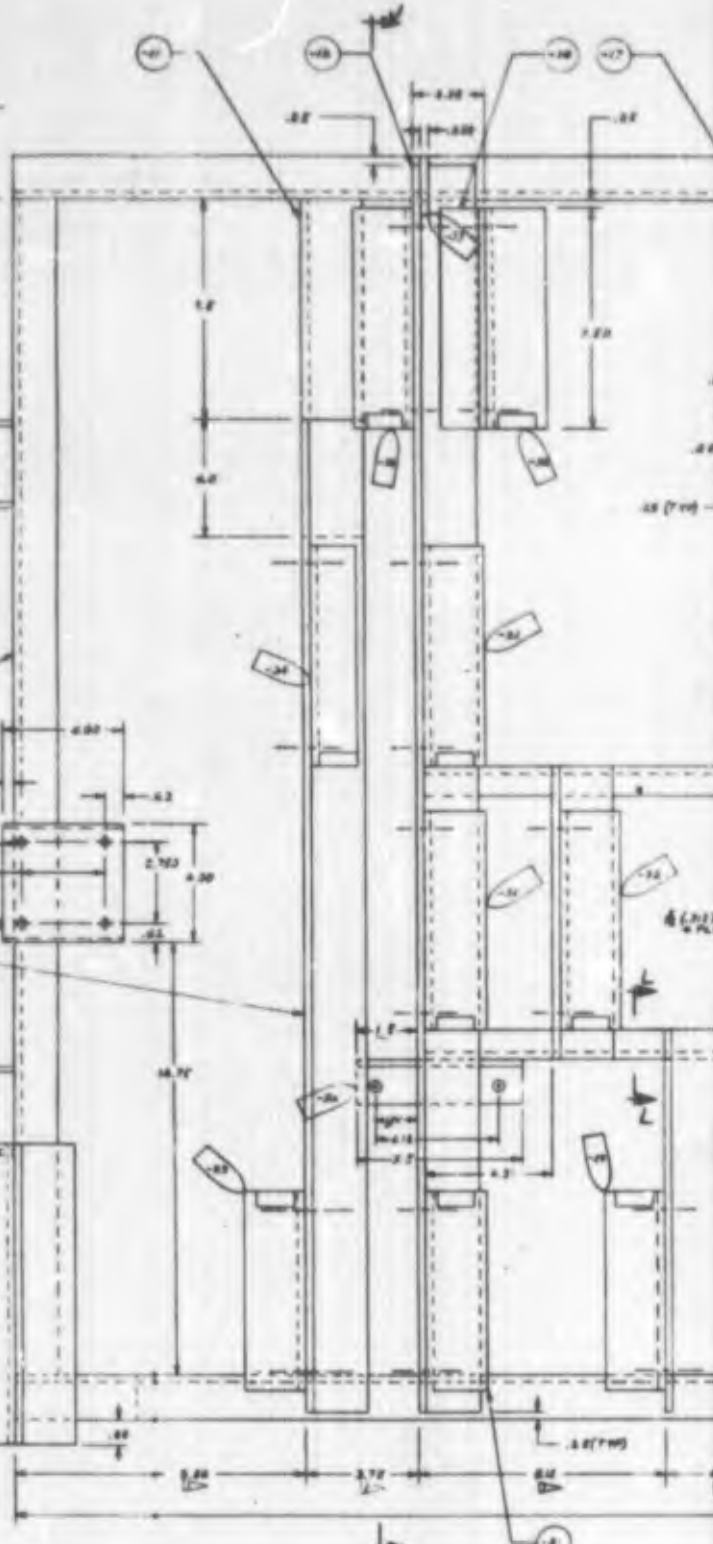
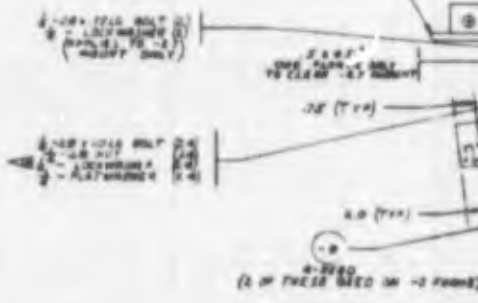




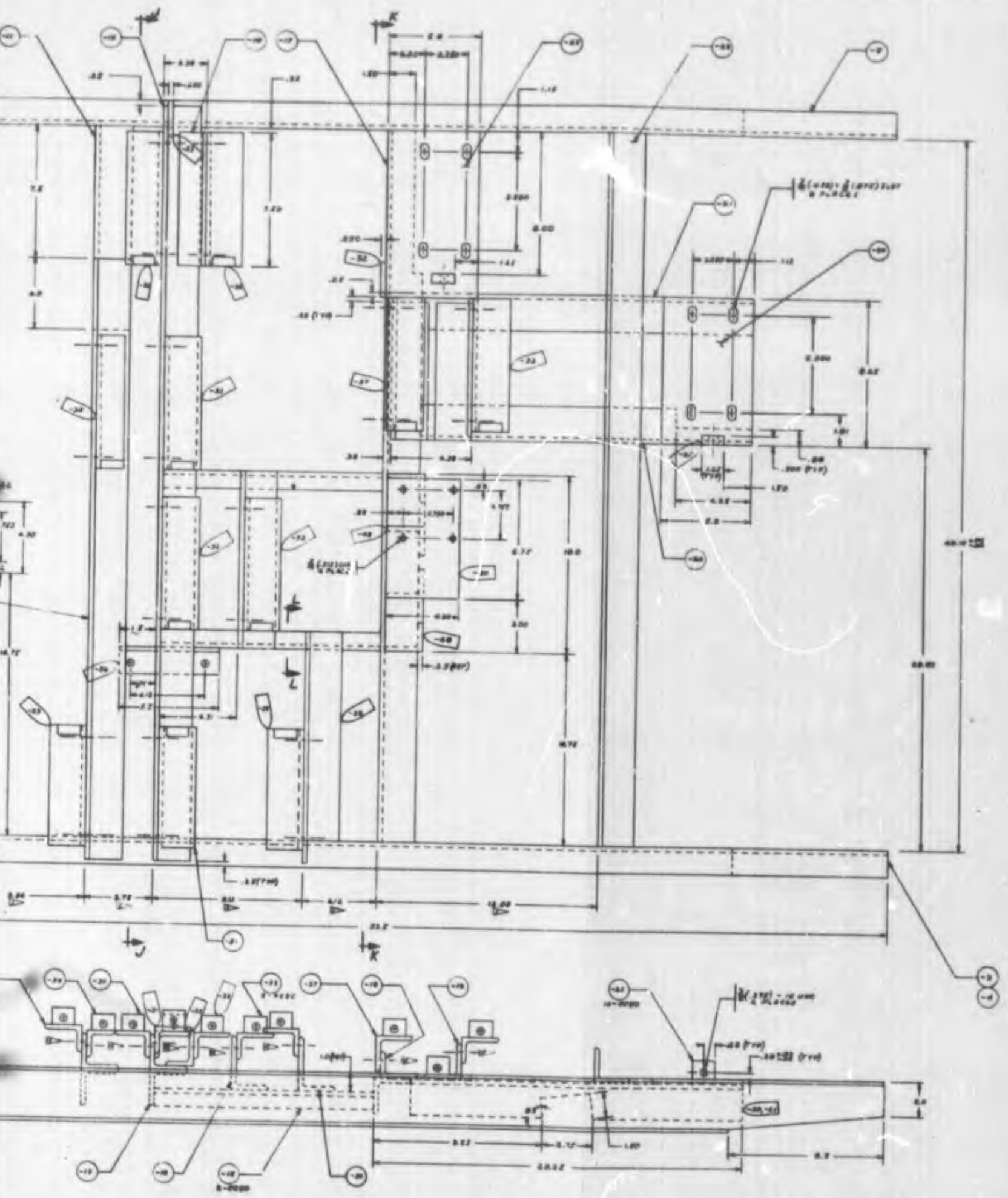
SECT. L-L  
SCALE: 1/2\"/>



VIEW N-N  
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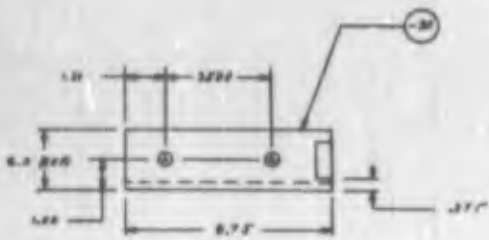
A



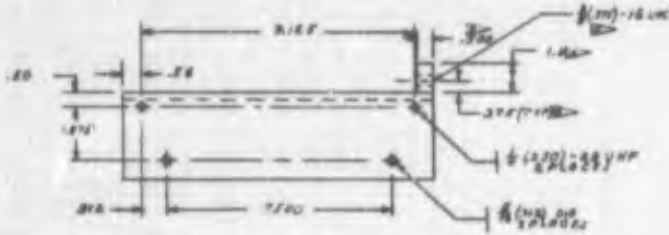
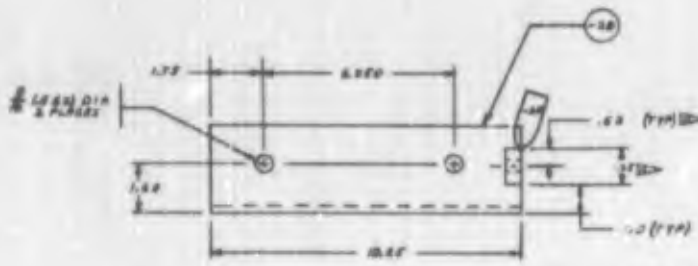
-3 FRAME

Figure 19. Resin Pump Drive Frame (b)

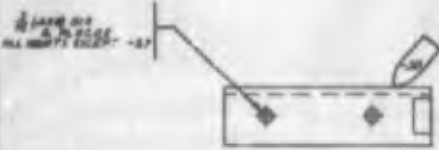
B



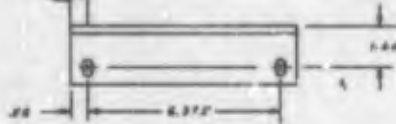
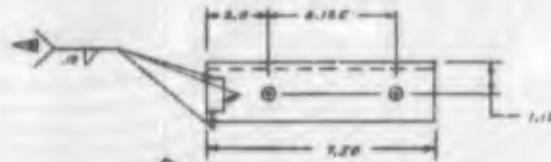
-29 MOUNT



-27 MOUNT



-31 MOUNT  
DIM 3MM OR -0.00



-37 MOUNT

- THE NUMBERING FOR -21, -22, -23, -24, -25, -27, -28, -29, -30, -31, -32, -33, -34, -35, -36, -37, -38, -39, -40, -41, -42, -43, -44, -45, -46, -47, -48, -49, -50, -51, -52, -53, -54, -55, -56, -57, -58, -59, -60, -61, -62, -63, -64, -65, -66, -67, -68, -69, -70, -71, -72, -73, -74, -75, -76, -77, -78, -79, -80, -81, -82, -83, -84, -85, -86, -87, -88, -89, -90, -91, -92, -93, -94, -95, -96, -97, -98, -99, -100, -101, -102, -103, -104, -105, -106, -107, -108, -109, -110, -111, -112, -113, -114, -115, -116, -117, -118, -119, -120, -121, -122, -123, -124, -125, -126, -127, -128, -129, -130, -131, -132, -133, -134, -135, -136, -137, -138, -139, -140, -141, -142, -143, -144, -145, -146, -147, -148, -149, -150, -151, -152, -153, -154, -155, -156, -157, -158, -159, -160, -161, -162, -163, -164, -165, -166, -167, -168, -169, -170, -171, -172, -173, -174, -175, -176, -177, -178, -179, -180, -181, -182, -183, -184, -185, -186, -187, -188, -189, -190, -191, -192, -193, -194, -195, -196, -197, 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Figure 19. Resin Pump Drive Frame (c)

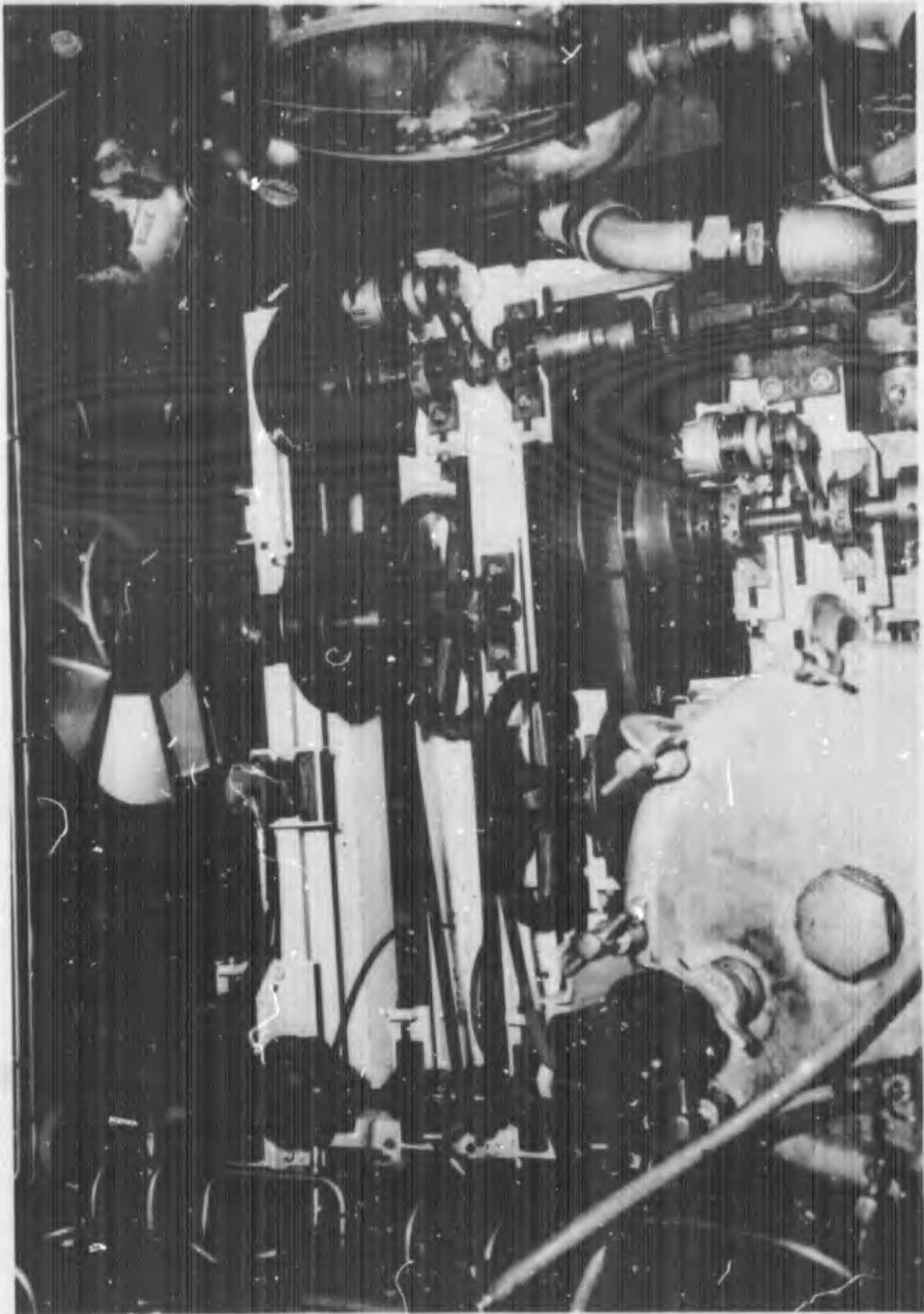
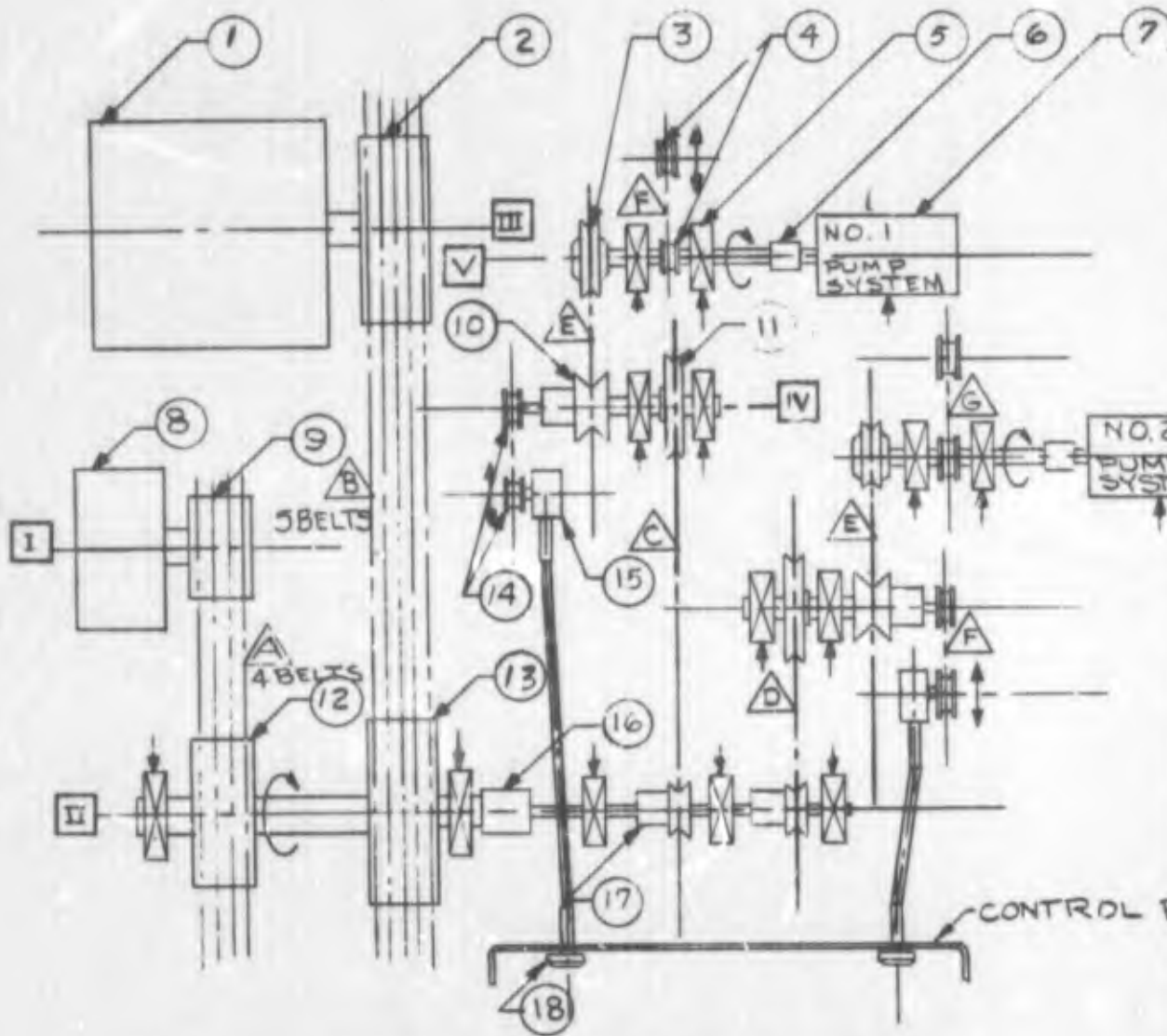


Figure 20. Resin Pump Tachometer Generator

- | ITEM | NOMENCLATE             |
|------|------------------------|
| 1    | COMPRESSOR             |
| 2    | SHEAVE 23.5 OD.        |
| 3    | AUTO. PULLEY           |
| 4    | TIMING PULLEY 1.91 PD. |
| 5    | PILLOW BLOCK           |
| 6    | COUPLING               |
| 7    | PUMP                   |
| 8    | PTO                    |
| 9    | SHEAVE 7.9 OD          |
| 10   | VARI SPEED PULLEY      |
| 11   | PULLEY 10.6 PD.        |
| 12   | SHEAVE 10.5 PD.        |
| 13   | SHEAVE 18.4 PD.        |
| 14   | TIMING PULLEY 1.91 PD. |
| 15   | REDUCTOR               |
| 16   | COUPLING               |
| 17   | AIR CLUTCH 2.7 PD      |
| 18   | SPEED CONTROL          |



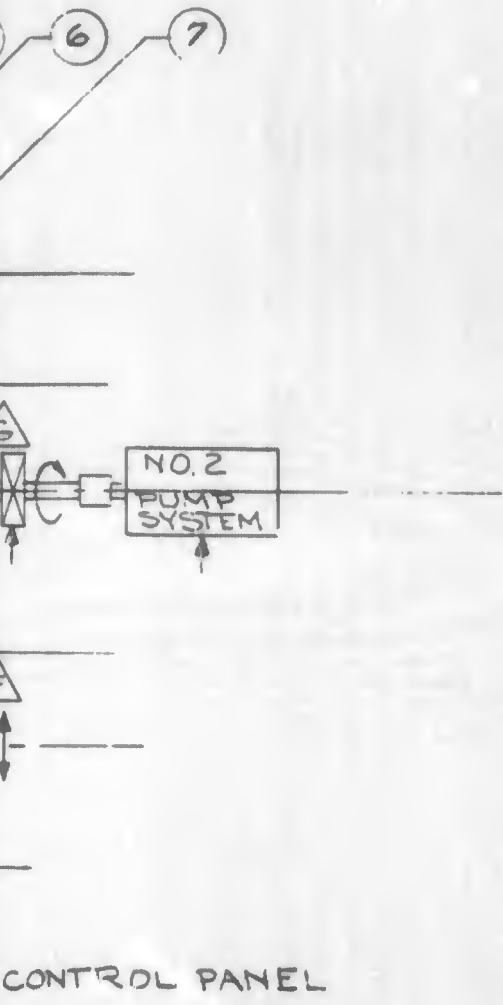
SCHEMATIC-POWER TRANSFER SYSTEM

SHAFT	RPM	AVAIL. HP
I	1500	23.68
II	1120	23.68
III	870	20.00
IV	287	3.00
V	VARIABLE 30 TO 788	1.84

PUMP DATA						
HORSEPOWER & FLOW @ 200 PSI						
SPEED (RPM)	VISCOSITY (SSU x 1000)					
	2.5	7.5	25	100*	250*	
100						
150						
200						
250	HP	.95	1.1	1.2	1.5	1.7
	GPM	4.1	4.1	4.1	4.0	4.0
300	HP	1.1	1.35	1.45	1.75	2.0
	GPM	5.0	5.0	5.0	4.9	4.8
350	HP	1.2	1.5	1.6	1.85	2.1
	GPM	6.0	6.0	5.5	5.3	5.2
400	HP	1.35	1.6	1.8	2.1	2.4
	GPM	6.7	6.7	6.0	5.7	5.6

\* DATA FOR 100,000 & 250,000 SSU, ESTIMATED.

Figure 21. Power Transmission Schematic



1. BELT TENSION DATA:

ADJUST LOCATION OF PILLOW BLOCKS (WITH SET SCREWS INDICATED BY SYMBOL ↑) UNTIL EACH BELT CAN BE DEFLECTED  $\frac{1}{64}$ " PER INCH OF SPAN WITH THE FOLLOWING LOAD APPLIED AT CENTER OF SPAN:

BELT	LOAD	
▲ A	10 lbs	} ADJUST IN SEQUENCE
▲ B	5 lbs	
▲ C	2 lbs MIN.	
▲ D	2 lbs MIN.	

DEFLECTION SHOULD NOT EXCEED MORE THEN  $\frac{1}{4}$ " AT APPROX. CENTER OF SPAN WITH LIGHT LOAD APPLIED WITH THUMB OR FINGER

TENSION IN EACH BELT SHOULD BE CHECKED AFTER FIRST HOUR OF RUN FOR TENSION DECAY

FOR EACH SHAFT, ADJUST PILLOW BLOCKS IN EQUAL INCREMENTS, KEEPING ALL SHAFTS PARALLEL WITHIN .06

2. PUMP SYSTEM NO. 1 SAME AS PUMP SYSTEM NO. 2 EXCEPT AS SHOWN
3. SERVICE REQTS:
  - A. GREASE PILLOW BLOCKS EACH 10 HOURS OF OPERATION
  - B. CHECK PTO EACH 2 HOURS OF OPERATION. FILL WITH SAE 50 NON DETERGENT ENGINE OIL
  - C. SERVICE AND ADJUST COMPRESSOR AND PUMPS PER BINKS MFG CO AND VIKING PUMP CO. MAINTENANCE MANUAL IN EQUIP. OPER. INSTRUCTIONS AND MAINTENANCE DATA MANUAL

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pulley number  $\triangle$  was used. To provide an infinitely variable speed to the pumps, the transmission assembly shown in Figures 18 and 20 was used. Pump rpm can be adjusted while system is running (by the operator at the control panel,) through the flex shaft (Figures 18 and 20) and gear reductor to the variable transmission by positive grip timing belts. Pump speeds ranging from 90 rpm to approximately 500 rpm at 1150 rpm constant main jack shaft speed were available at either pump. Resultant flow rate from the pumps can be infinitely adjustable from 1.5 to 7 gallons per minute, at pressures up to 200 psi. At reduced pressures, the flow rate can be increased to over 9 gallons per minute, depending on resin viscosity.

The air actuated clutches are controlled from the operator's panel (Figure 22) by a control valve, providing instant ON-OFF capability. This control is interlocked with the control for the resin outlet valves, necessitating the resin pump to be disengaged before the resin valve is closed. This prevents build up of maximum pump pressure and resultant increased pump wear.

The post-Europe drive system also includes a tachometer generator (Figure 20) for each of the resin pumps, with indicators mounted on the control panel. The indicators (Figure 23) read in 10 rpm increments for fine adjustment of the resin pump speed, corresponding to a pump output change of 1/25 gpm for each 10 rpm change.

An easily removable safety grating was provided over the drive system to protect personnel from possible injury. It also provides an area on which to store hoses and miscellaneous items during short moves.

#### b. Increased Diameter Resin Lines and Spray Hoses

As described in Section V of this report, the European tests indicated the possibility of excessive suction losses in the resin pumping system or excessive pressure drops in the system, or both. Following the European tests, a complete theoretical analysis of resin flows from 1 gpm to 7 gpm was conducted. The analysis was based on B-3-B resin at varying temperatures (40°F through 80°F) with average viscosities as shown on Figure 24.

To confirm the results of this analysis, flow tests were conducted on the pre-Europe system at room and reduced temperatures. To minimize costs, the tests were basically field type tests and the low temperature tests were conducted with resin that was cooled in the tank trailer by ambient storage overnight during February. Figures 25, 26 and 27 show the test setup and Figure 28 is a graphical comparison between one of these test runs and the equivalent theoretical calculation. This is a representative comparison of test data and calculated data at low temperatures, and, as shown, the pressure drops were approximately the same. However, for the suction lines, the calculations indicated smaller losses at low temperature than those actually measured during the test. At higher

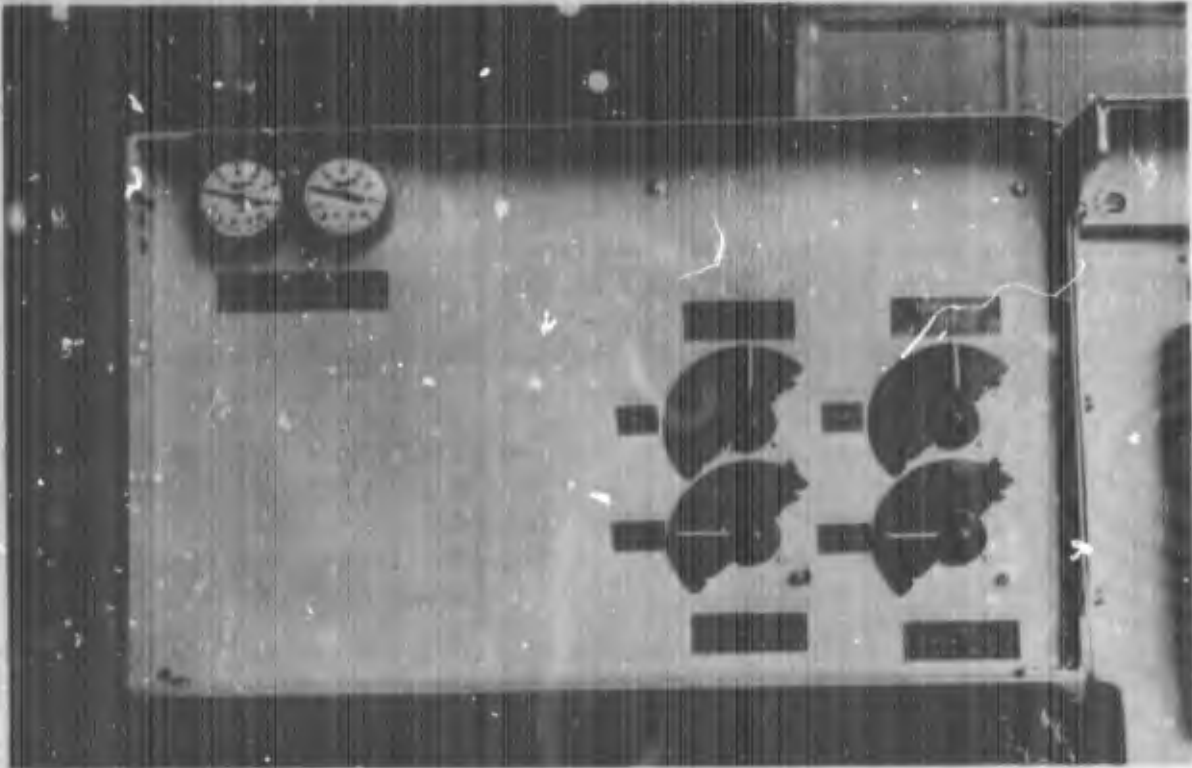


Figure 22. Resin Pump Clutch Control

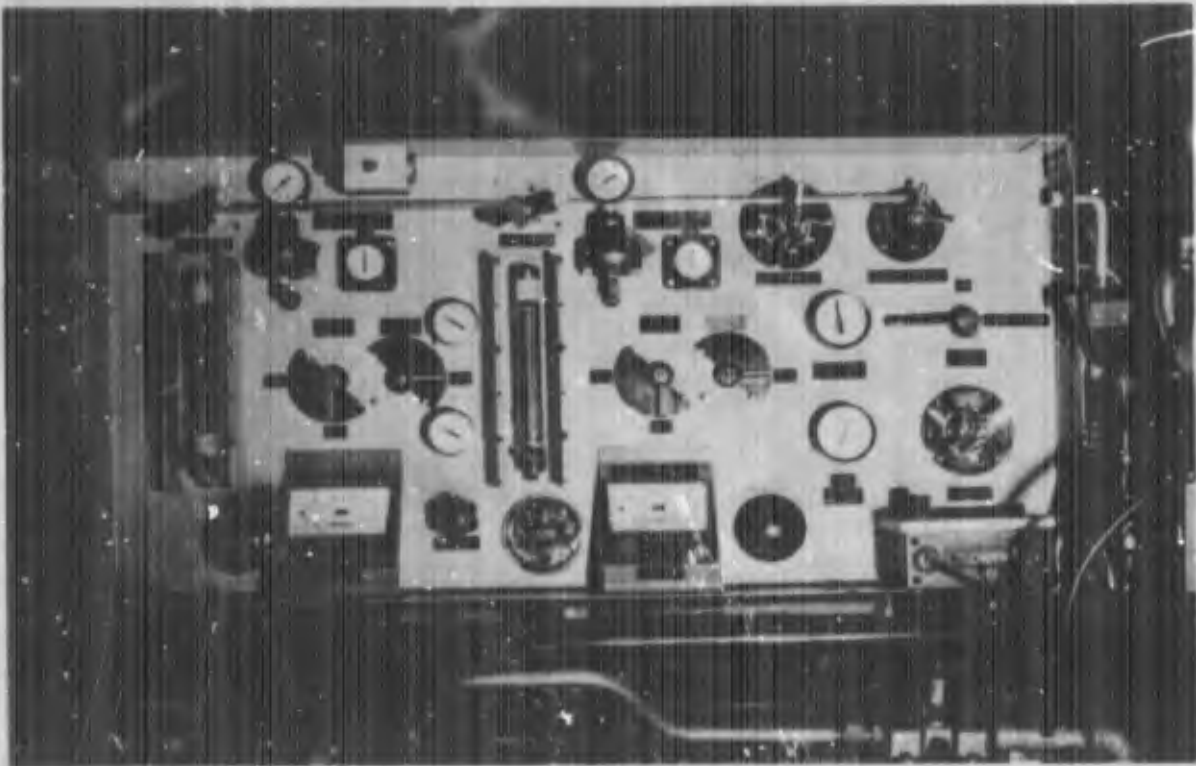
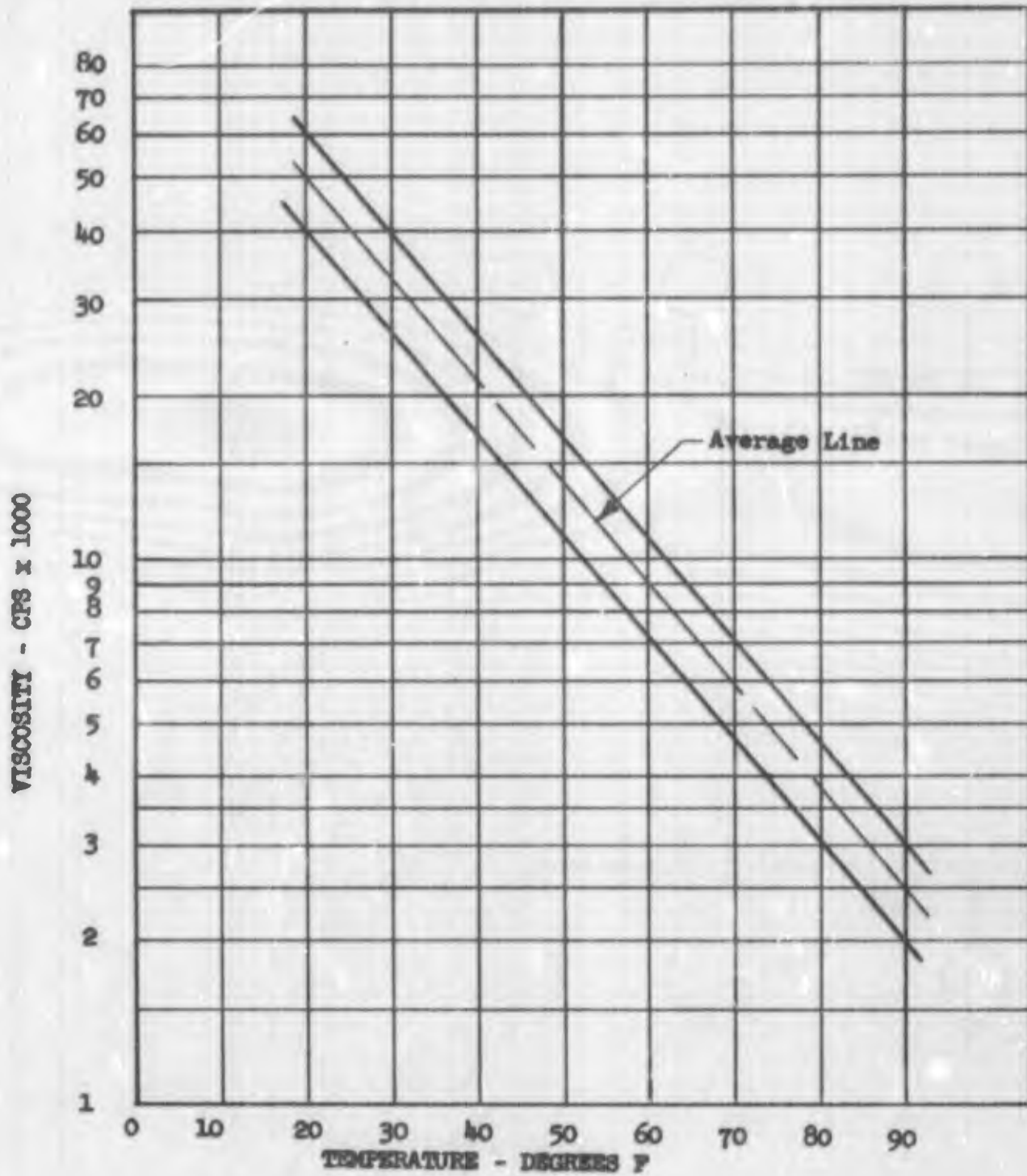
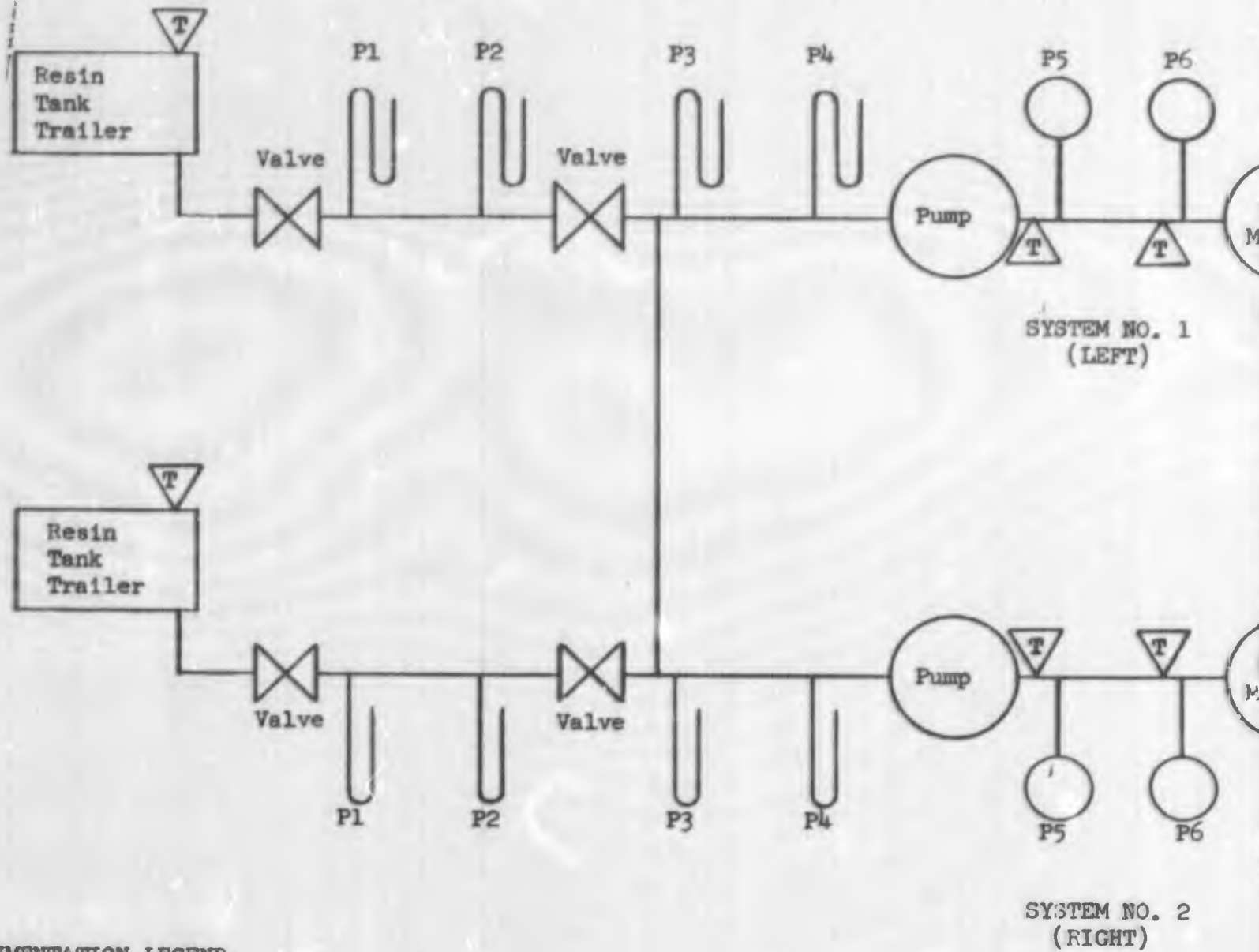


Figure 23. Operator's Control Panel






**NOTE:** The average line shows a theoretical plot for B3B Resin. However, viscosities within the band reflect the spread experienced in measured values during actual tests.

Figure 24. Viscosity vs Temperature

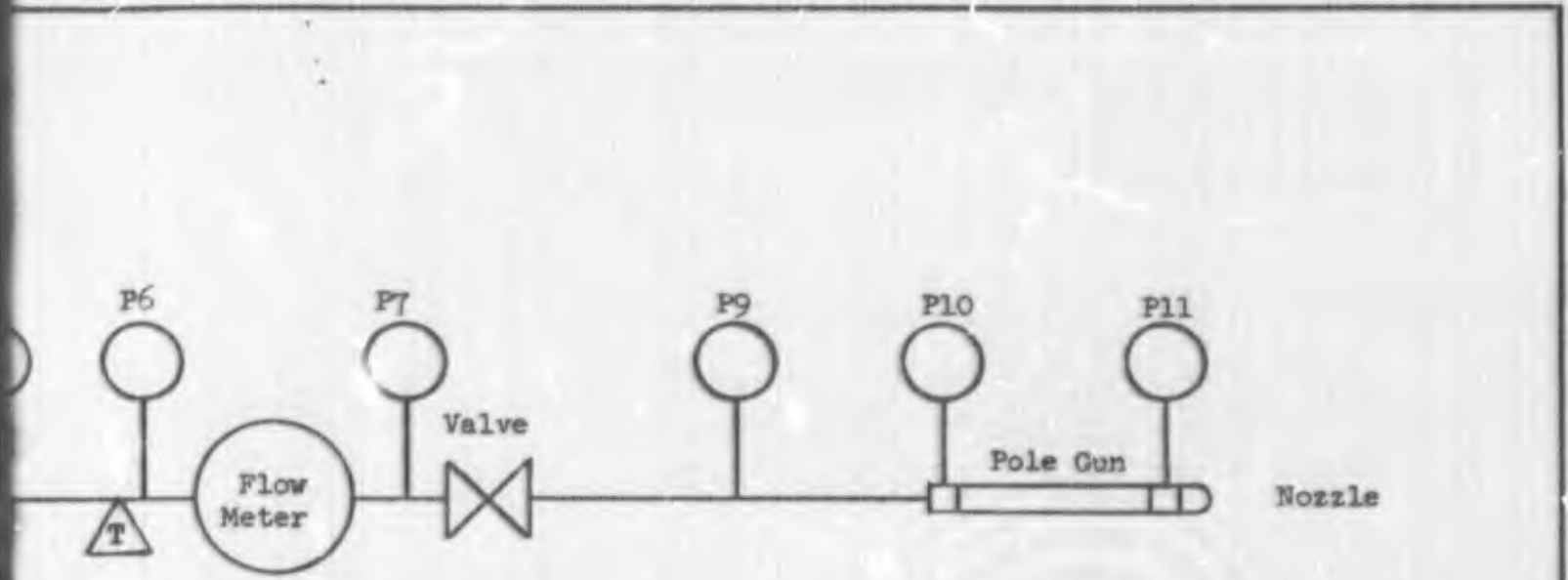


INSTRUMENTATION LEGEND:

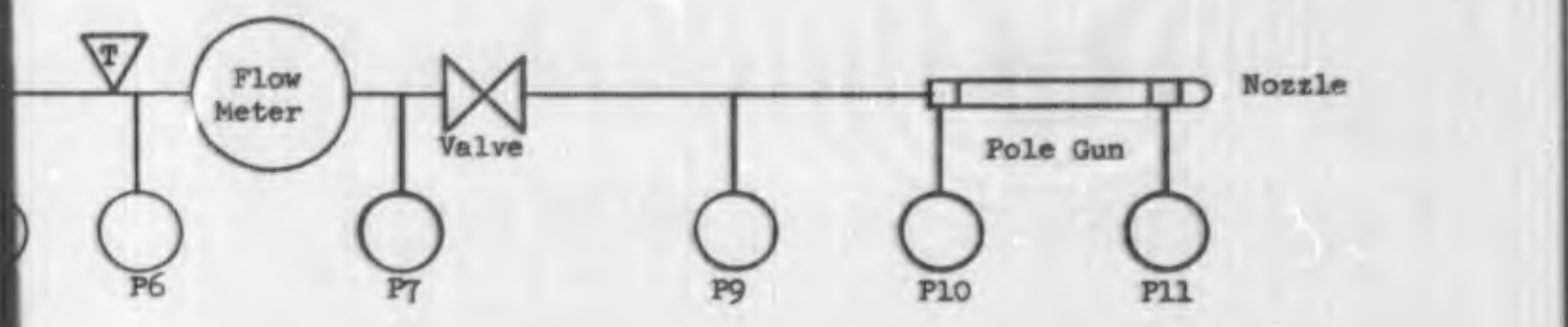
-  TEMPERATURE GAGE
-  MANOMETER (SUCTION)
-  PRESSURE GAGE (DISCHARGE)

NOTE: Pre-Europe System - Reference Figure 15 for Plumbing Details

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EM NO. 1  
(LEFT)



EM NO. 2  
(RIGHT)

Figure 25. Diagram of Resin System Pressure and Temperature Instrumentation

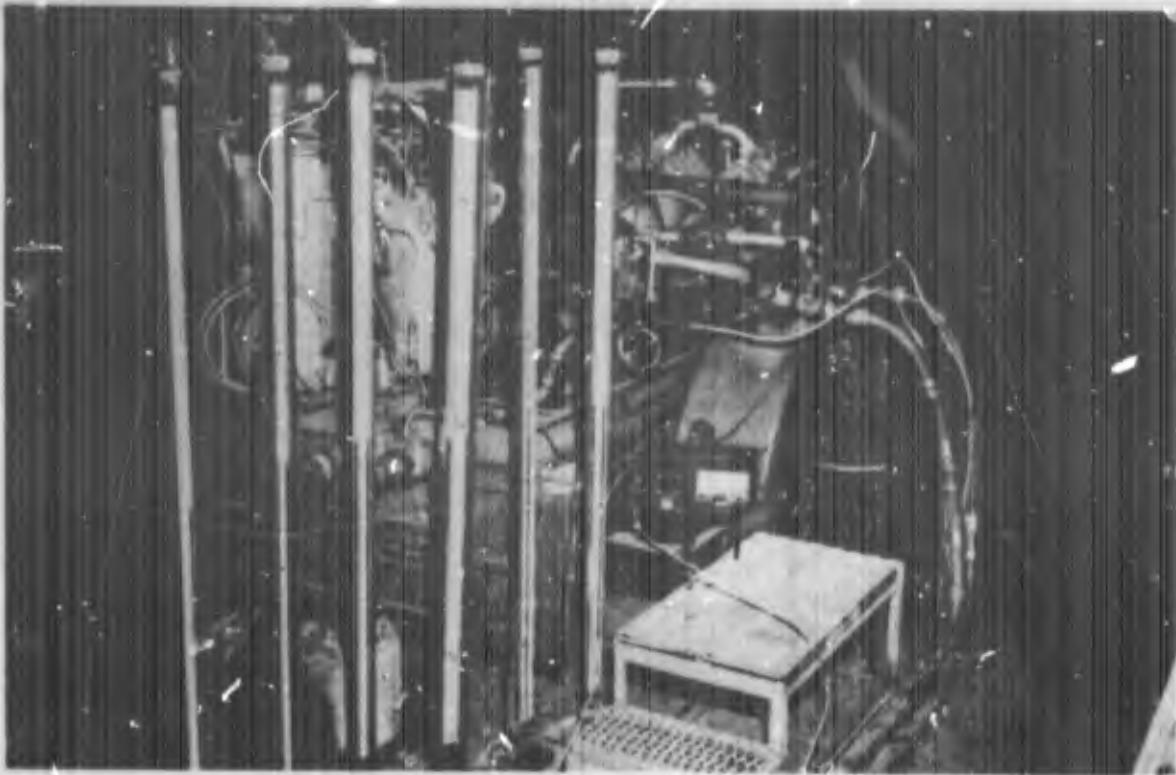


Figure 26. Prime Mover - Resin Flow Test



Figure 27. Prime Mover - Resin Flow Test Operation

PRESSURE DROP - PSIG

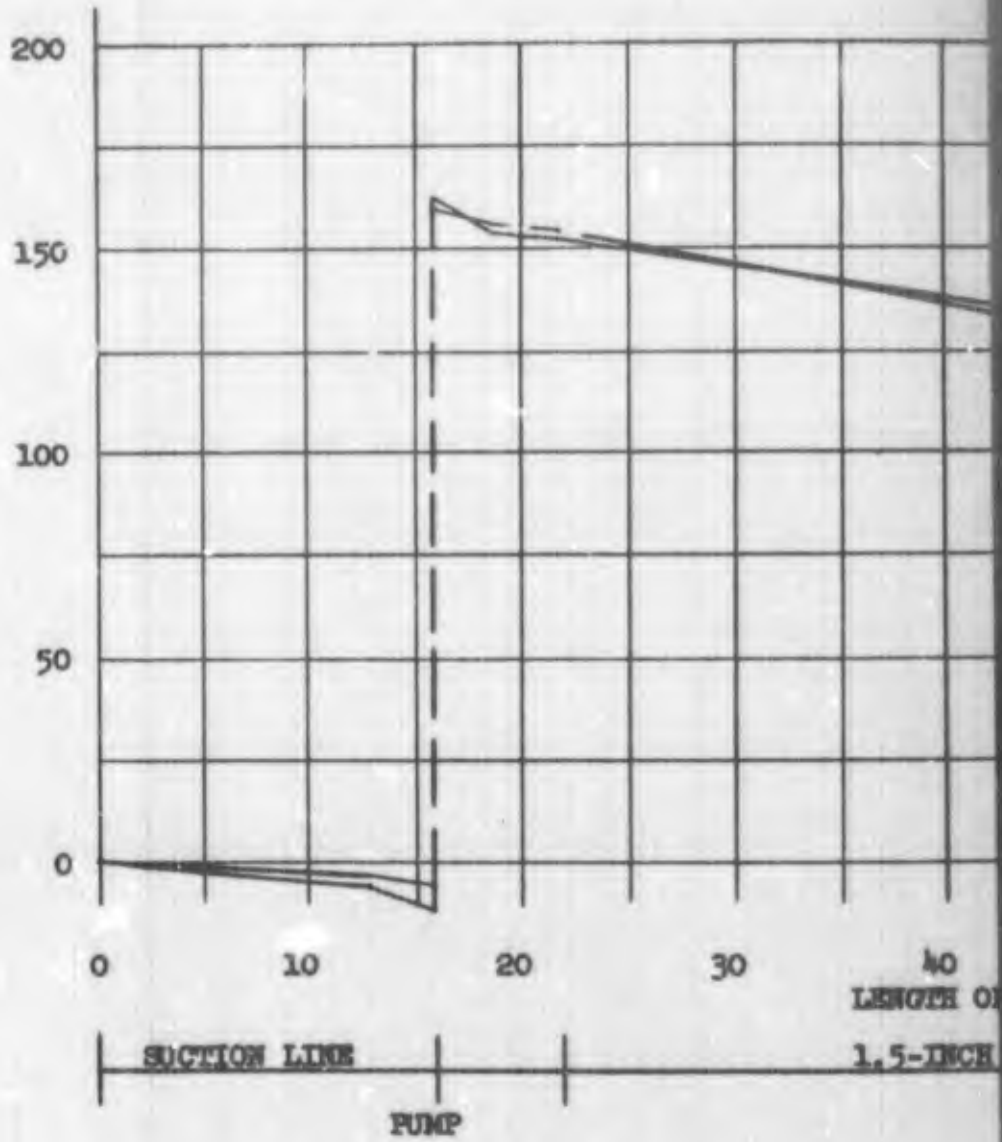
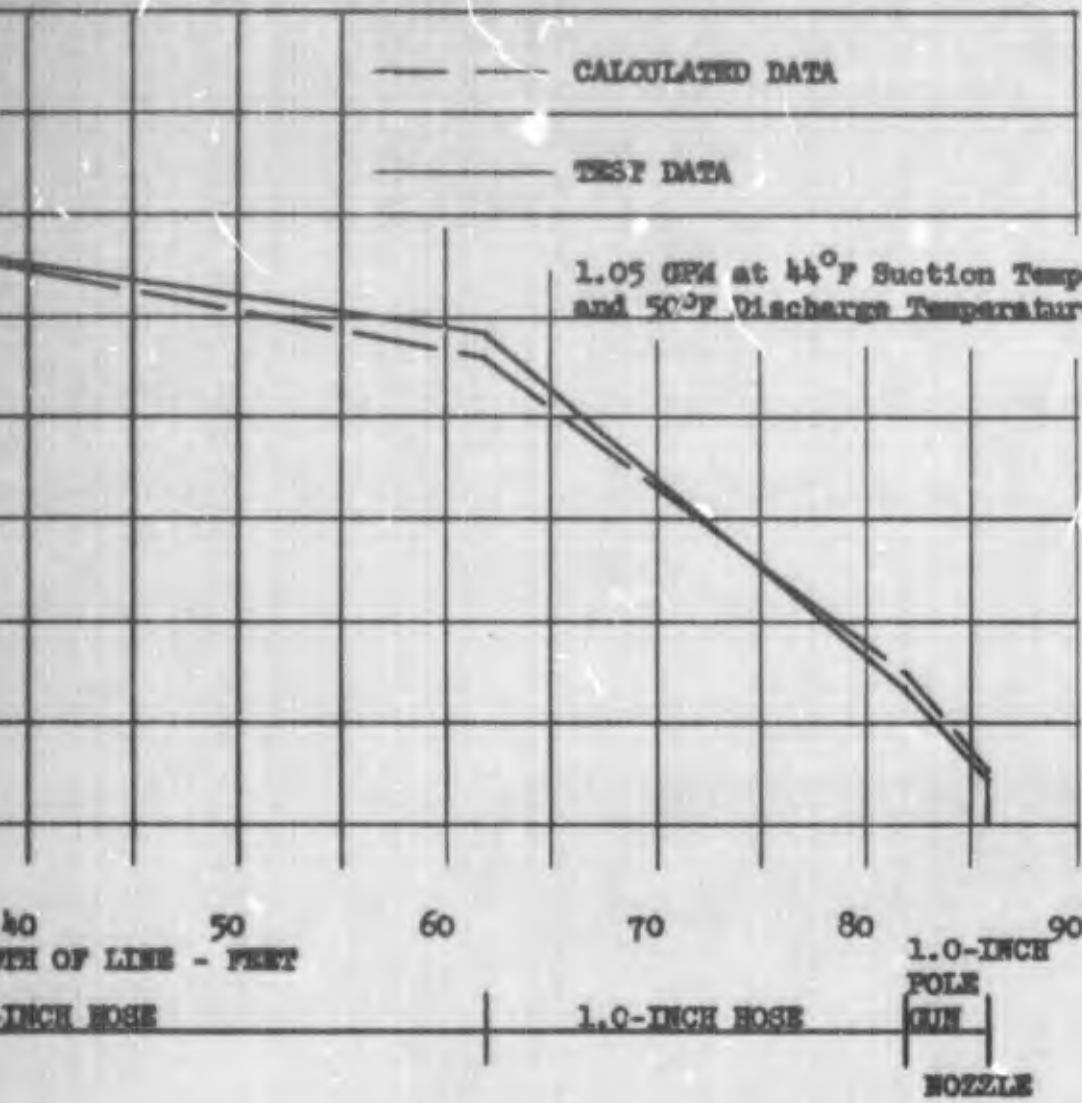


Figure 28. Appli vs Th

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Application Equipment Pressure Drop Characteristics, Rapid Site Phase I, Pre-Europe Test  
 vs Theoretical Calculations (B-3-B Resin)

B

temperatures, the calculated suction losses were in approximate agreement with test data, but some deviation was noted in the discharge pressure losses. It is possible that a portion of the observed deviation, calculation vs test, is attributable to the spread in viscosities noted in Figure 24.

Based collectively on field experience, test information and theoretical analysis, certain resin plumbing changes were felt required to provide adequate flow rates at low temperatures. These changes were:

Increase suction plumbing diameter from 2.5 to 3 inches.

Increase discharge plumbing from the combination 1.5 and 1 inch system to 2 inches. However, as of the date of this report, the post-Europe configuration has not been fully completed because of schedule limitations.

Modifications were limited to those considered absolutely necessary for the immediate usage of the equipment at Eglin and Edwards Air Force Bases.

A summary of calculated pressure drops at various flows and temperatures is shown on Figure 29 for the present post-Europe plumbing. For comparison, a similar curve for the pre-Europe system is shown based on the average viscosities shown on Figure 24. Configurations I, II A, and II B use a 2 1/2-inch suction line. Configuration III is based on a 3-inch suction line which will probably be installed on the equipment during Phase II.

It is planned that further tests and analyses will be conducted during the Phase II rapid site program.

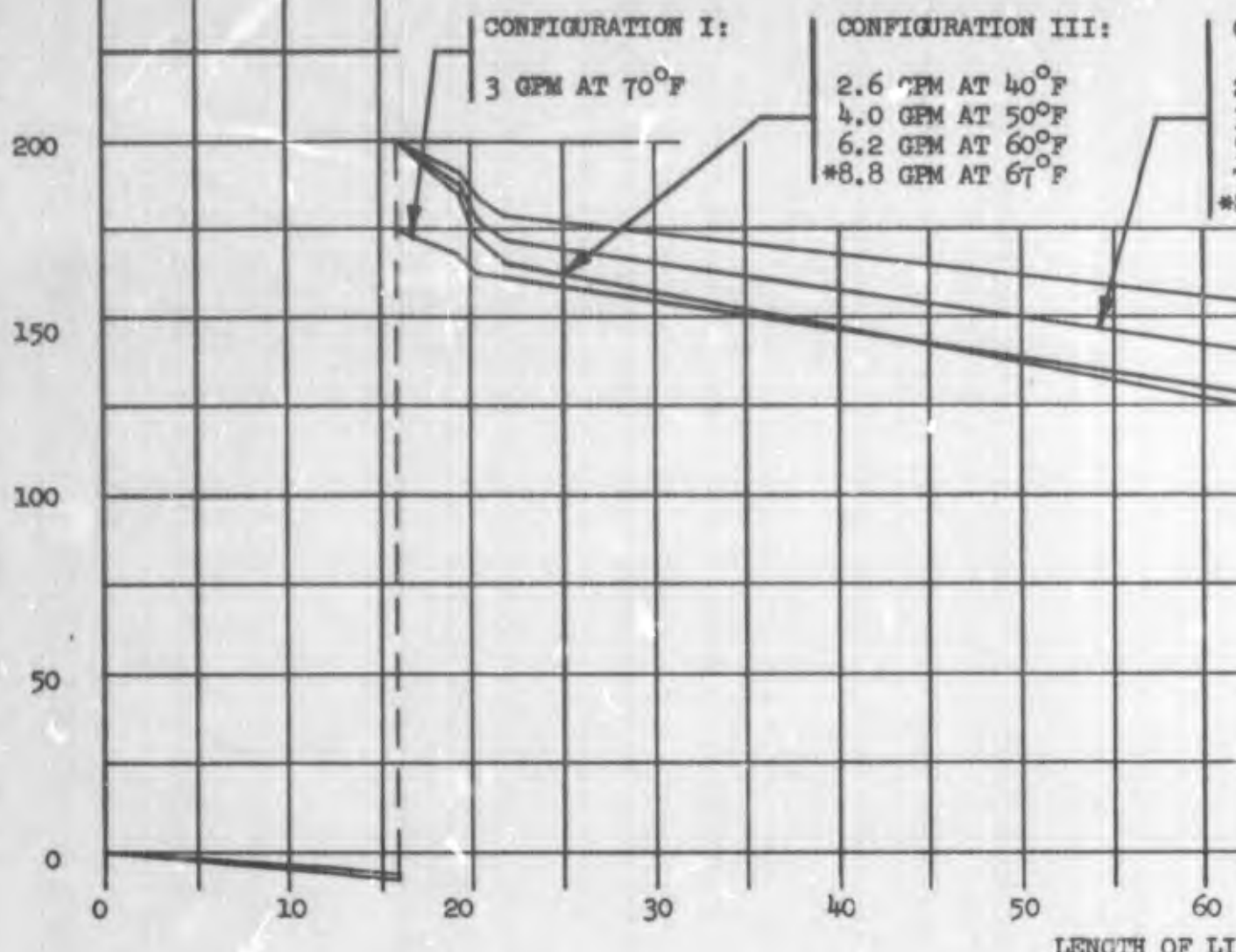
Objectives of this work will include more accurate determinations of the effects of shear rate and agitation on resin viscosity, under both suction and pressure conditions.

#### c. Quick Acting Resin Shutoff Valves

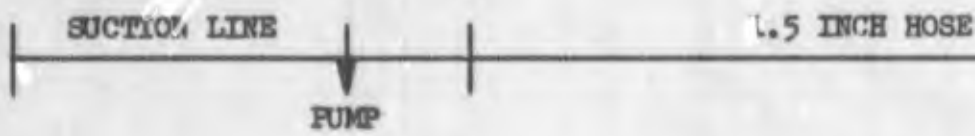
Operational experience during the European tests showed that the manually operated resin shutoff valves on the prime mover resin spray hoses were unsatisfactory. During site application with pole guns, there were frequent periods when it was desirable to shut off the resin flow for short periods of time. This could not be done rapidly with the manual valves. Secondly, with the resin pressure shutoff at the prime mover, resin continued to flow from the pole gun because of the diametral stretch in the spray hose.

To correct the foregoing conditions, the resin shutoff valves on the prime mover were replaced with the pneumatically operated valves shown in Figure 30. These valves are operated with a four-way pneumatic valve on the control panel. The four-way valve is interlocked with the air valve which controls the resin pump "on-off" clutch to assure that the clutch cannot be engaged if the resin outlet valve is closed.

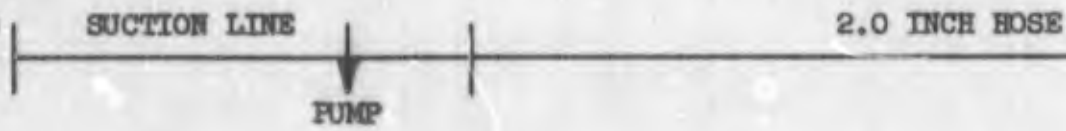
PRESSURE DROP - PSIG



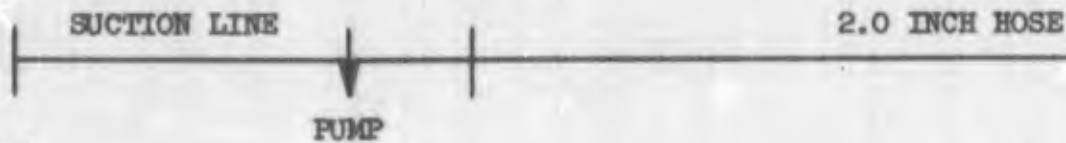
CONFIGURATION I  
(PRE-EUROPE)



CONFIGURATIONS II A & B  
(POST-EUROPE)



CONFIGURATION III  
(POST-EUROPE, LESS  
1.5 INCH HOSE AND  
SUCTION LINE DIA.  
INCREASED TO 3 INCHES)



A

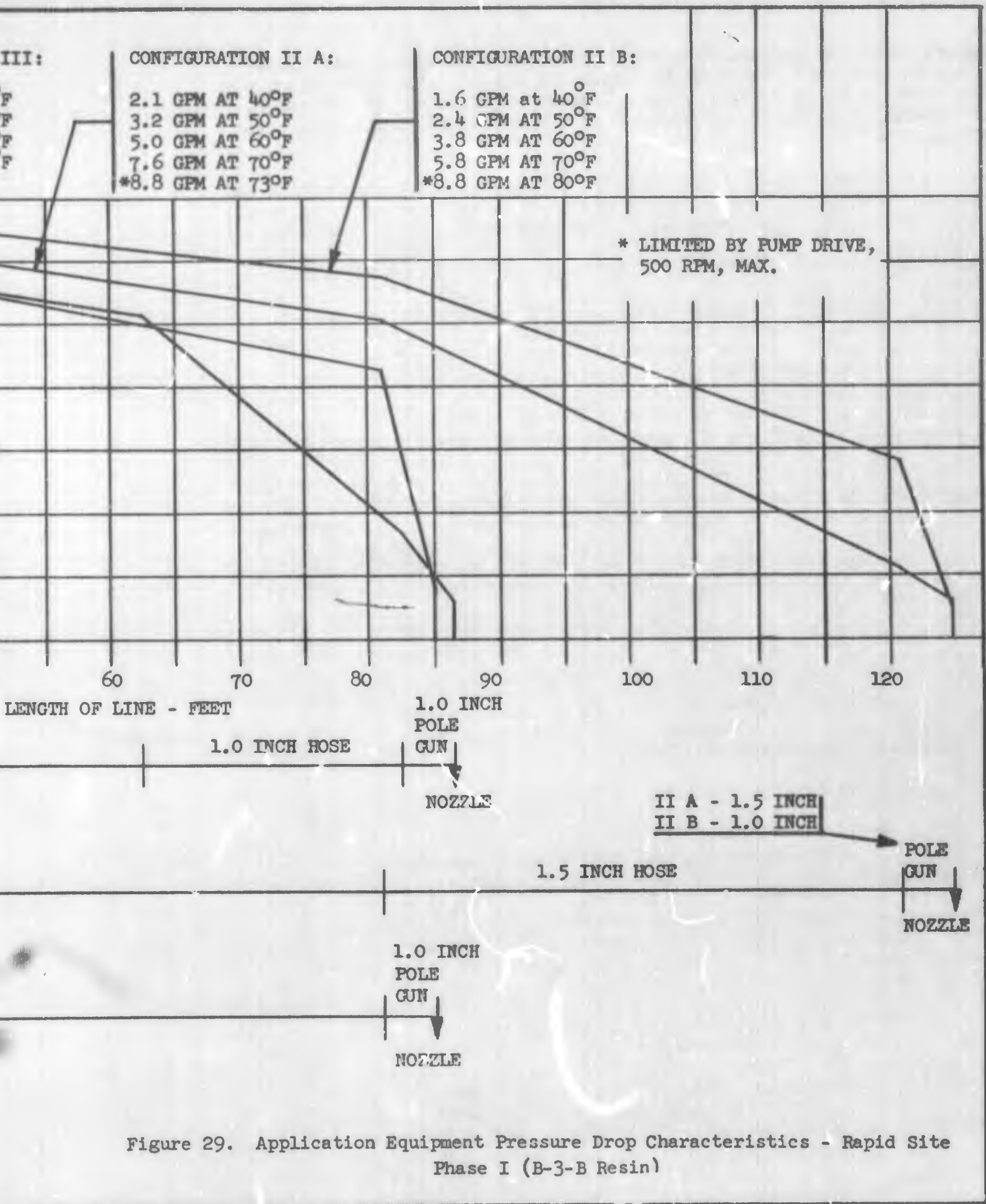


Figure 29. Application Equipment Pressure Drop Characteristics - Rapid Site Phase I (B-3-B Resin)

B

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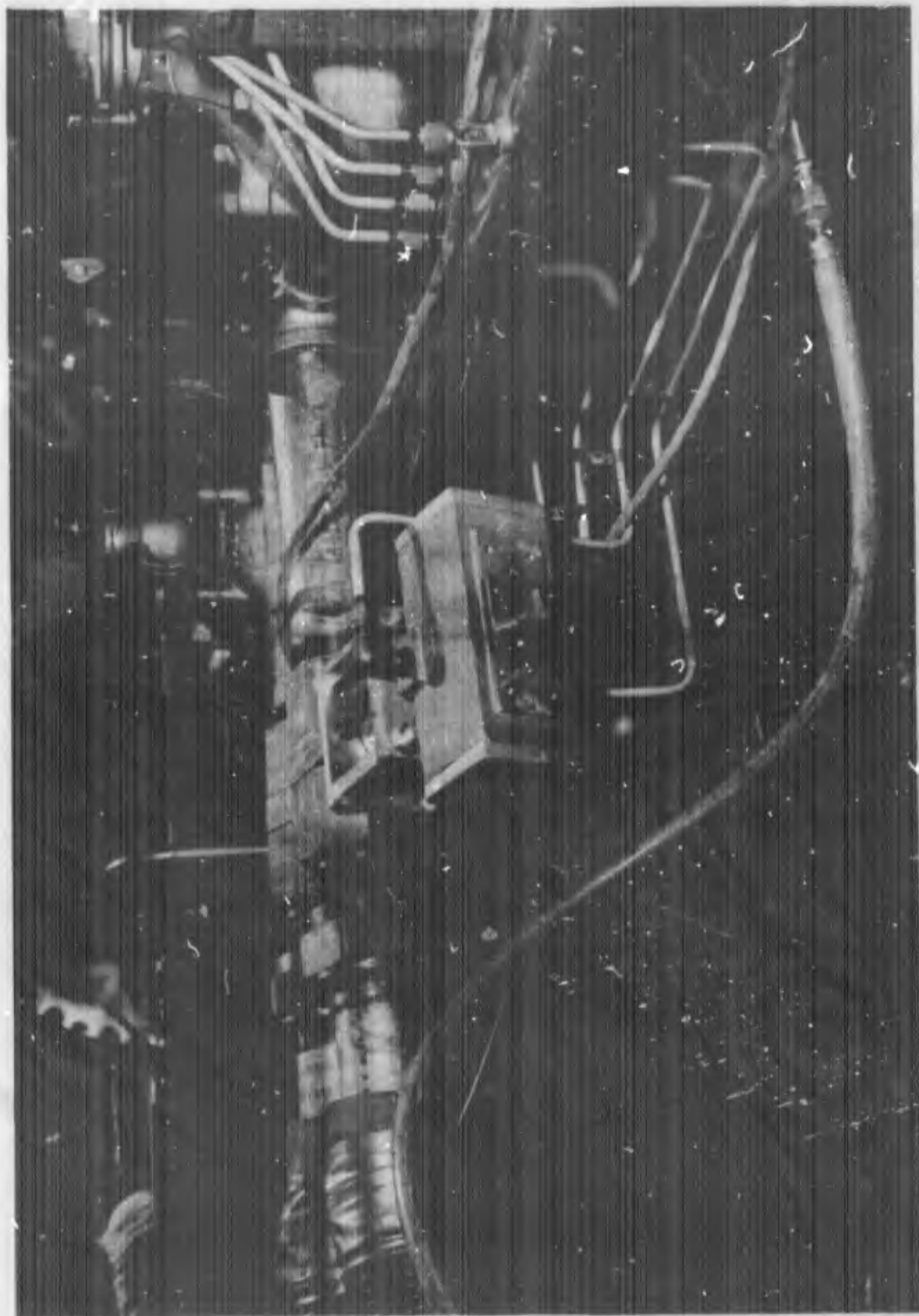


Figure 30. Quick-Acting Resin Shutoff Valves

#### d. Miscellaneous Prime Mover Modifications

Several minor modifications were made to the prime mover systems to improve operational deficiencies. Prior to the European tests, schedule limitations precluded final installation of the intercom system amplifier. During these tests, the amplifier was simply placed on the seat of the cab. Figure 31 shows the amplifier mount added during the post-Europe modifications. This mount places the amplifier over the right-hand seat area, which was considered a reasonable location in view of the fact that personnel other than the driver are seldom transported in the prime mover. Control knobs face the rear, making it possible to adjust them from either the driver's position or from the right-hand doorway. The figure also shows hooks provided prior to the European tests for storage of the intercom headsets.

A number of modifications were made to improve fluid system monitoring and control. As noted in Section V of this report, the catalyst injection system did not provide as high a catalyst flow for a given flowmeter reading during the European tests as it did during pre-European checkout. Consultation with the catalyst supplier provided an indication of the reason for this: a high sensitivity of catalyst viscosity to temperature. It was suspected that at low temperatures, increased catalyst viscosity might induce a higher flowmeter reading at a given flow rate than at higher temperatures. A flow test was conducted on the catalyst system which confirmed this, and also revealed the need for a higher capacity flow meter tube to be used during cold weather. Wallace and Tiernan, the flowmeter manufacturer, recommended the proper low temperature tube, and this unit was purchased and installed. Details of the proper tube usage for given temperature conditions are specified in Reference 4. This reference also includes a calibration curve form which will be completed during Phase II for use by the control panel operator.

Two temperature gages were added to the control panel to assist the operator in selecting the proper catalyst flowmeter reading for a given resin flow rate. These gages appear in Figure 23 just to the left of the catalyst flowmeter for system number two. The lower gage is a probe-type unit which is inserted in a fitting through which catalyst flows before entering the flowmeters. Temperatures read on this gage are used by the operator to select the required catalyst flowmeter reading (in percentage of full flow) for a given resin flow rate. The upper gage is a similar probe-type unit, mounted on an insulated plate which includes a perforated white shroud for the probe, and is used to measure free air temperature. Temperature measured on this gage is used by the operator to select the percentage of catalyst to be used for the resin to effect proper cure rate. The reading is also used as a basis for selecting percentages of promoter ingredients to be used.

The small electrical box shown in the lower right-hand corner of the control panel on Figure 23, together with the microphone shown with it, was utilized during site preparation at LTV in April 1966 in conjunction with a public address system speaker mounted on the right-hand front bumper of the prime mover. The box is an amplifier, and provides the

operator with volume and "on-off" controls for the system. The toggle switch mounted on the upper flange of the control panel is part of the intercom system. It is moved to the left for operator communication with the resin spray operator number 1, to the right for spray operator number 2. (The public address system was evaluated for use in application operations in which the number of operating personnel exceeds the number of available headsets in the intercom system.)

The pre-Europe catalyst system included a line mounted filter (item 42, Figure 15). While useful in filtering out contaminants which might affect the accuracy of the catalyst flowmeters, the filter was difficult to service. For the post-Europe modification program, the filter was removed from the system and replaced with a plain flared tube union. A screen, mounted on the end of the standpipe in the catalyst pot, was installed to replace the filtering action of the line mounted unit, as shown in Figure 32. This unit can be checked each time the pot is refilled, and replacement or cleaning is more readily accomplished.

Paragraph b, page 98 of this report described analysis and tests conducted to determine resin system pressure drops and the resultant modifications made to the resin system plumbing and spray hoses. Figures were also presented in that section which will be used as a guide in future operations in selecting proper combinations of flow rates and maximum hose lengths for given resin temperatures. To assist the operator in making these selections, and to serve as an indication of system performance, resin temperature and pressure gages were added to the system, as shown in Figure 33. The temperature gage is mounted on system number one only.

Two changes were made to the fiberglass dispensing system. One of them was necessitated by the addition of the control panel extension shown in Figure 22. This added panel obscured the fiberglass system air pressure regulator gages from the view of the control panel operator, so they were moved to the upper left-hand corner of the control panel. The second change to the fiberglass system was made to improve system performance. During the European tests, it was observed that air pressure at the fiberglass pots dropped during operation of the pots from 30 psi to about 15 psi. Analysis indicated that this was caused, as might be expected, by line losses between the glass system regulators and the pots. (During the original pre-European design, this was not anticipated, since the pots were originally to be used while mounted on the vehicle fenders.) However, operational experience showed that the pots did not function reliably if glass hoses longer than 20 feet were used. As a result, the pots were placed on the ground during operation to permit the use of short glass hoses (but this necessitated the use of long air line hoses from the prime mover to the pots.) One solution of providing for line losses would have been to increase the output pressure from the glass system regulators, but this would have overpressurized the pots when glass flow was stopped. The solution finally selected is shown in Figure 34. An air pressure regulator set at 30 psi was installed at the incoming air connection on the glass pot. (Several regulators were evaluated for this application.) The



**Figure 31. Intercom Amplifier Mount**



**Figure 32. Catalyst Screen**

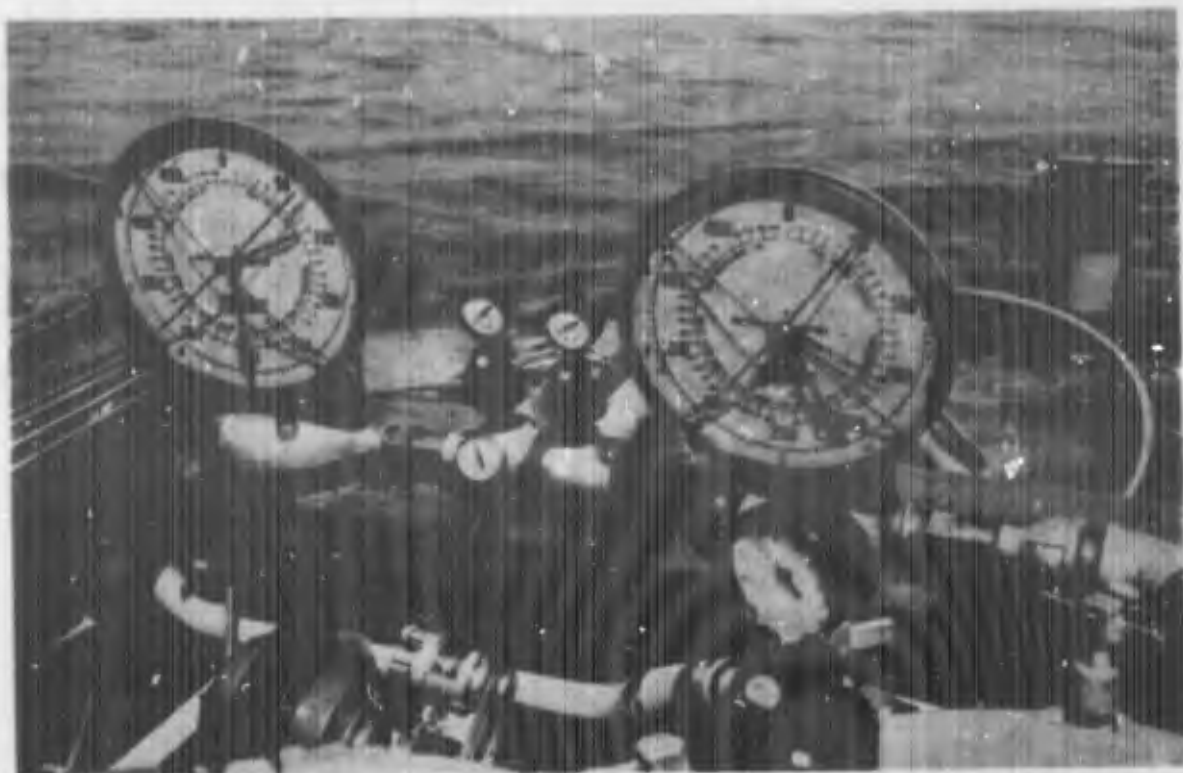


Figure 33. Resin Pressure Scale and Temperature Gages

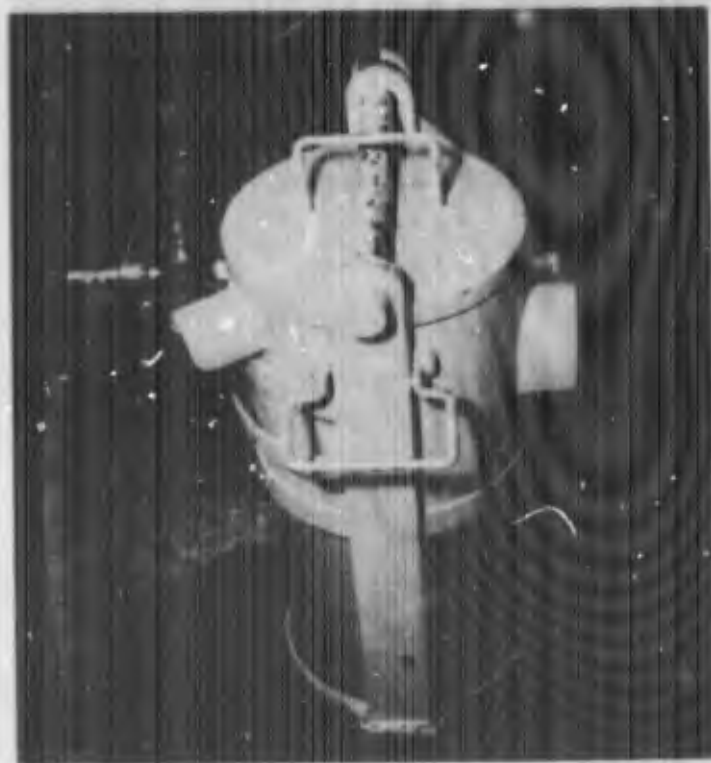


Figure 34. Pressure Regulator - Glass Pot

selected one is not shown in the figure, but is called out on the system schematic, Figure 35, paragraph 1, page 145. Addition of the regulator at the glass pot would permit removal of the upstream regulator. However, for the Phase I program and possible further testing in Phase II, the main regulator was left installed and will be adjusted to higher output pressures as required by the line losses.

Figure 36 shows two guide pins which were added to the soil disc (or "cookie-cutter") adapted plate which is installed on the left rear wheel of the prime mover. These pins were added to simplify installation of the disc attach bolts, providing support and proper positioning of the disc relative to the adapter plate while the bolts are being installed. The disc itself was also modified. Welded-on rings were added to the periphery to increase the width of the disc and widen the groove made by the disc in the terrain. In addition, an extension was added to the disc mounting surface which relocated the plane of the disc four inches further toward the outside edge of the prime mover wheel when installed. Both of these changes were made to correct deficiencies noted during the European tests; namely, difficulties experienced in spraying glass and resin into a narrow groove, and a tendency for the groove to collapse from tire loads imposed on the ground too close to the groove. Both of these changes are shown in Figure 37, paragraph g, page 120.

#### e. Improved Pole Guns

During European operations, certain inadequacies of the FM equipment pole guns and the LTV pole gun (Figures 16 and 17) became apparent, the most pronounced being the difficulty of maintaining a tuned condition during low flow rates. These guns also proved to be heavy and awkward over an extended period of use.

Because of these basic problems, redesign was instituted to provide:

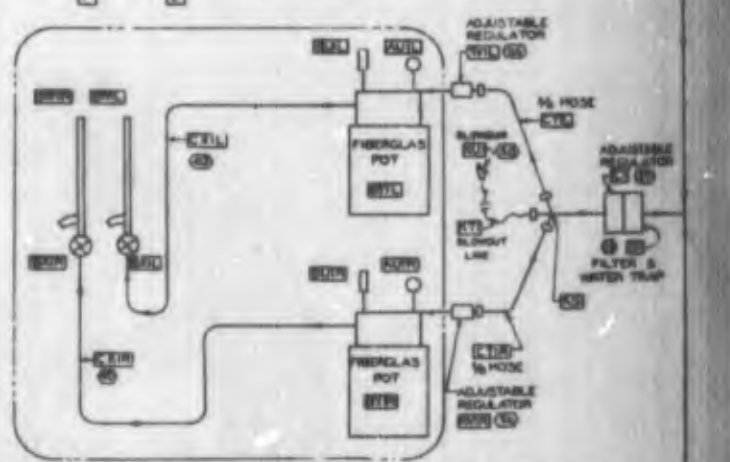
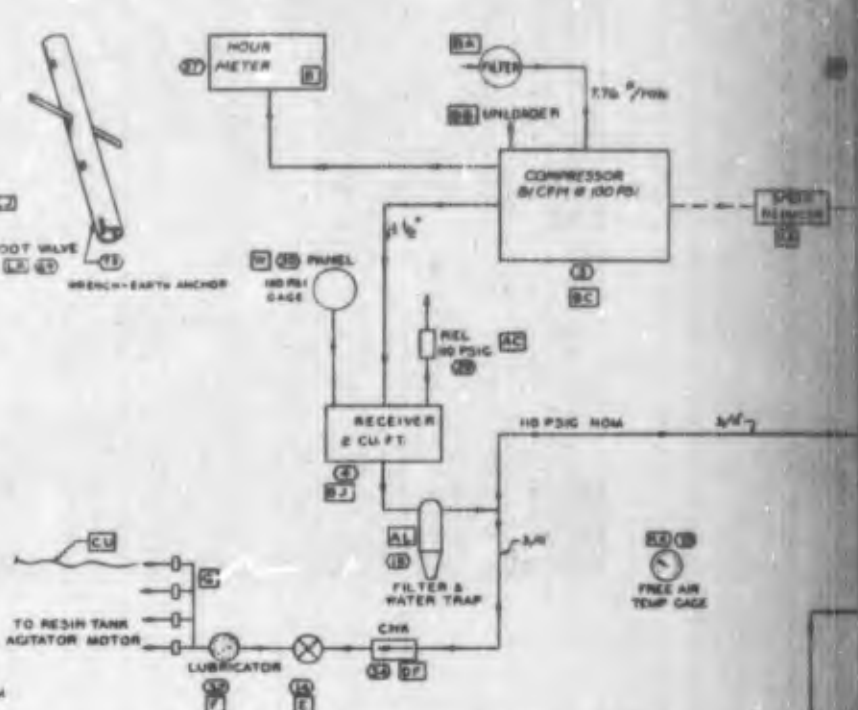
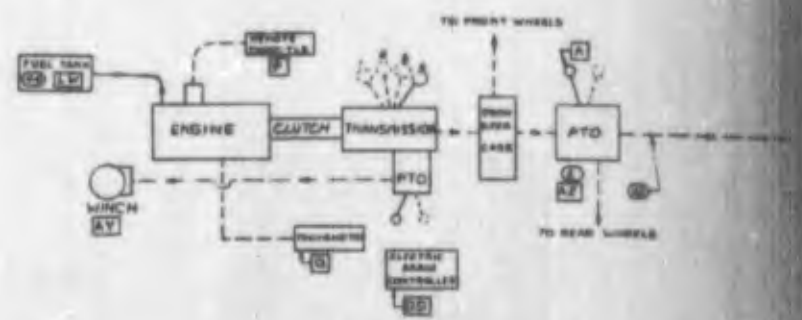
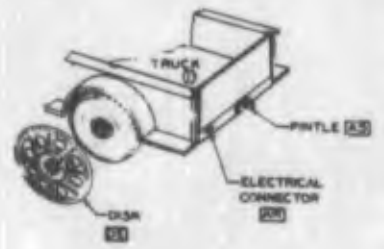
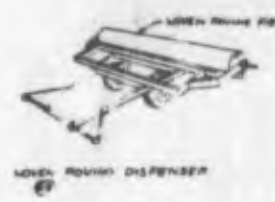
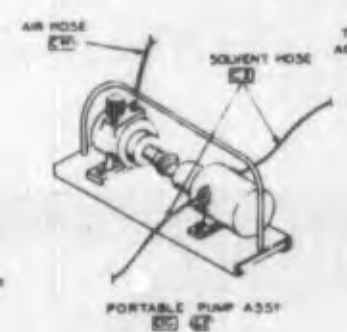
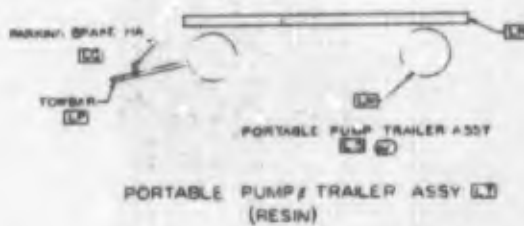
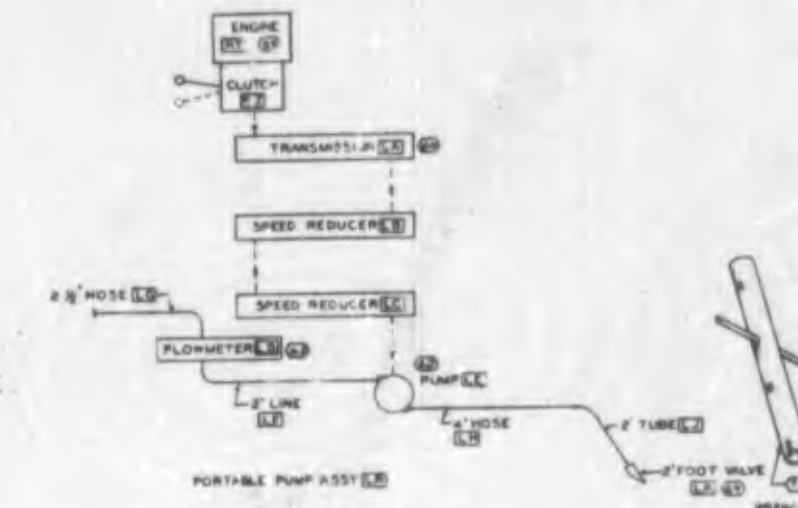
A pole gun capable of tuning at all resin flow rates

Easier handling over extended time intervals

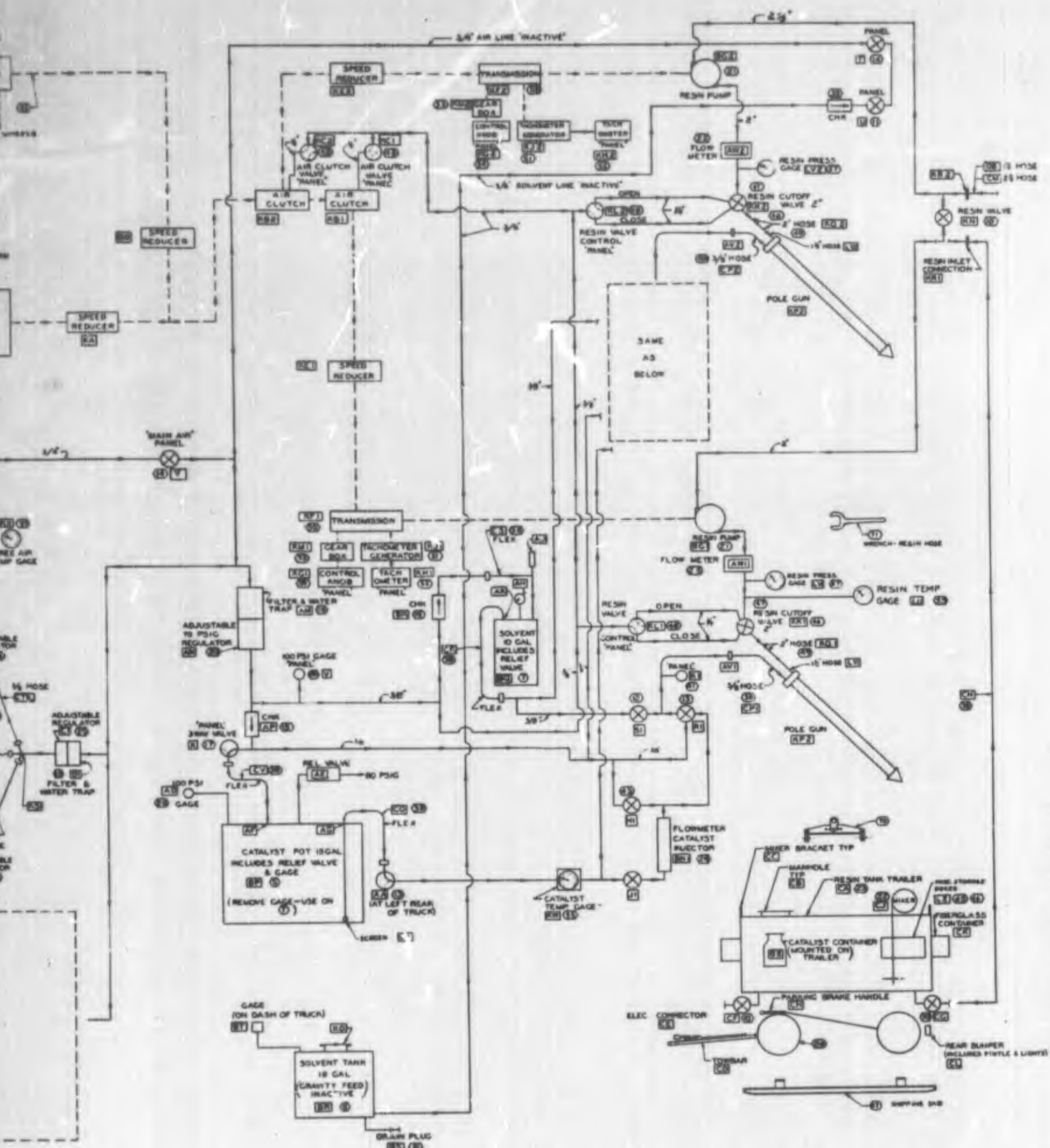
Reduced weight, or minimum weight to accommodate new resin hose requirements as discussed in previous paragraphs.

The problem of tuning was greatly reduced by the introduction of a catalyst injector nozzle (Figure 38) which used a series of small holes in the tapered plug. This nozzle provided the best tuning conditions and most uniform catalyst injection with the present resin being used. Complete testing is anticipated using various resin formulations and at varying temperatures to determine if a family of catalyst nozzles will be required or advantageous for varying operations.

Two basic design items were incorporated into the pole gun to reduce the awkwardness reported by the gun operators. First, swivel fittings were introduced to reduce the resistance to torsional rotation

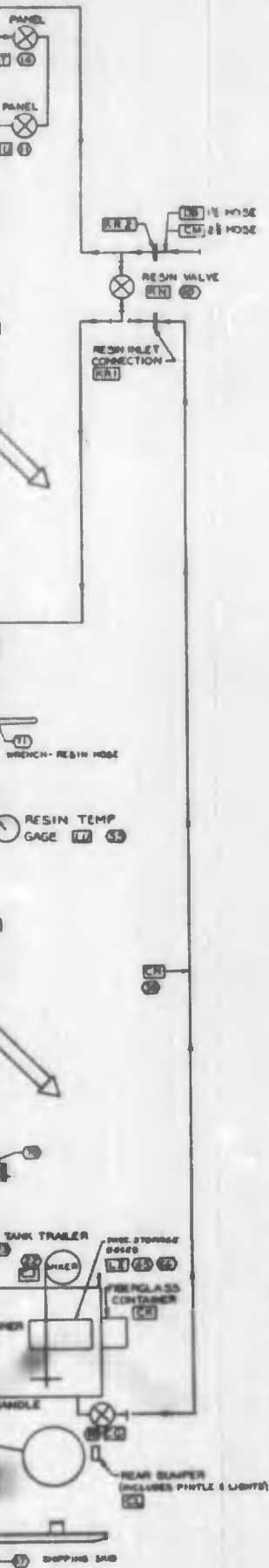


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NOTE:  
 1. ITEM NO. 1 THIS NO. IS SAME AS ON TO-ORDER COPY DELETED BY ITEM D. O. M. 00542, PRE EUROPE CONFORM  
 2. LETTERS IN BOLD REFER TO ITEM CALLOUTS IN SPS MANUAL.  
 ○ INDICATES ITEM NO. OF THIS DOC.

AMOUNT	TUBE	GALL
TEMP	P/N	P/N
NORMAL	100-000-000	000
LOW	100-000-000	000

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79	2		WRENCH-RESIN HOSE	79-0030	LTV	000000
79	1		HOIST BEAM, TRAILER	79-0038	LTV	000000
80	2		FIBERGLASS REFINER	79-0041	LTV	000000
81	1		PORTABLE PUMP	79-0050	LTV	000000
82	4		TANK TRAILER	79-0043	LTV	000000
83	4		TOOL BOX	79-0047	LTV	000000
84	2		TOOL BOX	79-0048	LTV	000000
85	1		FOOTVALVE	7	REPUBLIC	000000
86	1		FLOWMETER	100-000-000	REPUBLIC	000000
87	1		PUMP TRANSFER	100-000-000	REPUBLIC	000000
88	1		TRAILER ASSEMBLY	79-0043-2	REPUBLIC	000000
89	1		TRAINING MANUAL	79-0043-1	REPUBLIC	000000
90	1		SHOES (24 P)	100-000-000	REPUBLIC	000000

ITEM NO.	QTY	REQD	DESCRIPTION	SPC. PART NO.	SFC	REQUEST NO.
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179	2		RESIN HOSE	100-000-000	REPUBLIC	000000
180	2		RESIN HOSE	100-000-000	REPUBLIC	000000
181	2		RESIN HOSE	100-000-000	REPUBLIC	000000
182	2		RESIN HOSE	100-000-000	REPUBLIC	000000
183	2		RESIN HOSE	100-000-000	REPUBLIC	000000
184	2		RESIN HOSE	100-000-000	REPUBLIC	000000
185	2		RESIN HOSE	100-000-000	REPUBLIC	000000
186	2		RESIN HOSE	100-000-000	REPUBLIC	000000
187	2		RESIN HOSE	100-000-000	REPUBLIC	000000
188	2		RESIN HOSE	100-000-000	REPUBLIC	000000
189	2		RESIN HOSE	100-000-000	REPUBLIC	000000
190	2		RESIN HOSE	100-000-000	REPUBLIC	000000
191	2		RESIN HOSE	100-000-000	REPUBLIC	000000
192	2		RESIN HOSE	100-000-000	REPUBLIC	000000
193	2		RESIN HOSE	100-000-000	REPUBLIC	000000
194	2		RESIN HOSE	100-000-000	REPUBLIC	000000
195	2		RESIN HOSE	100-000-000	REPUBLIC	000000
196	2		RESIN HOSE	100-000-000	REPUBLIC	000000
197	2		RESIN HOSE	100-000-000	REPUBLIC	000000
198	2		RESIN HOSE	100-000-000	REPUBLIC	000000
199	2		RESIN HOSE	100-000-000	REPUBLIC	000000
200	2		RESIN HOSE	100-000-000	REPUBLIC	000000

Figure 35. Rapid Site Phase I System Schematic - Post-Europe

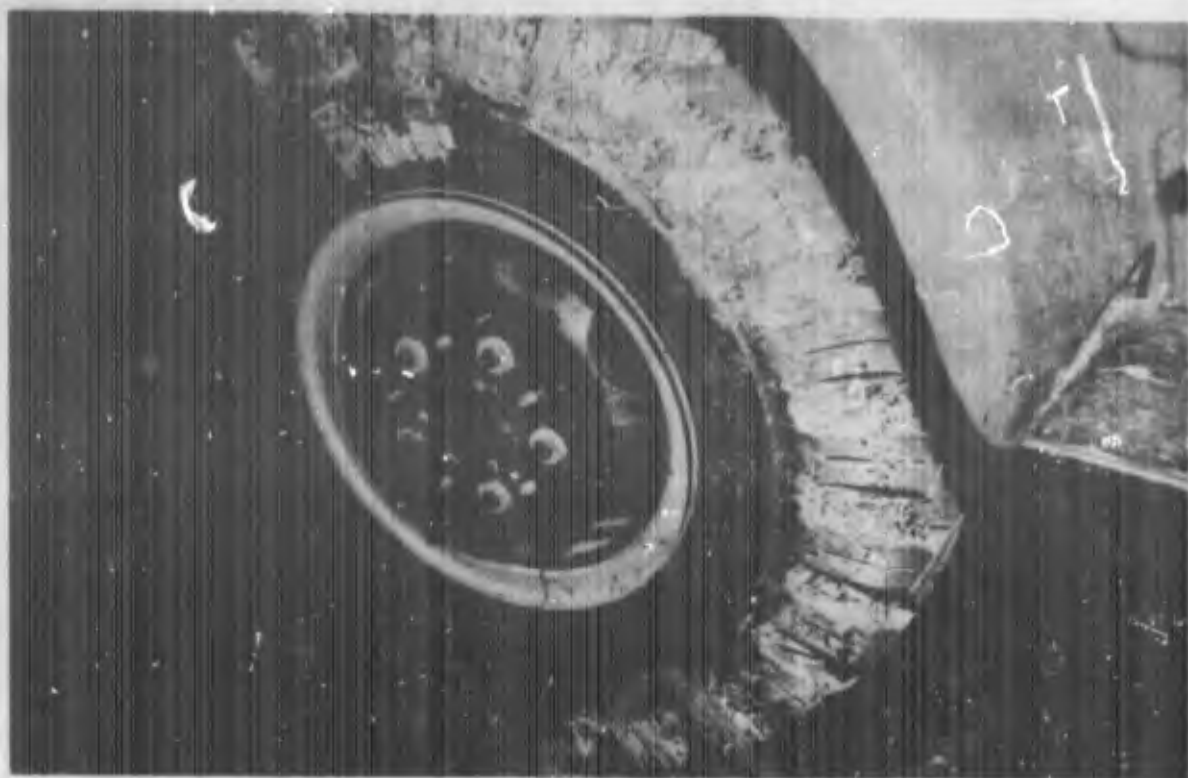


Figure 36. "Cookie Cutter" Disc Guide Pins on Right Rear Wheel of Dodge Truck

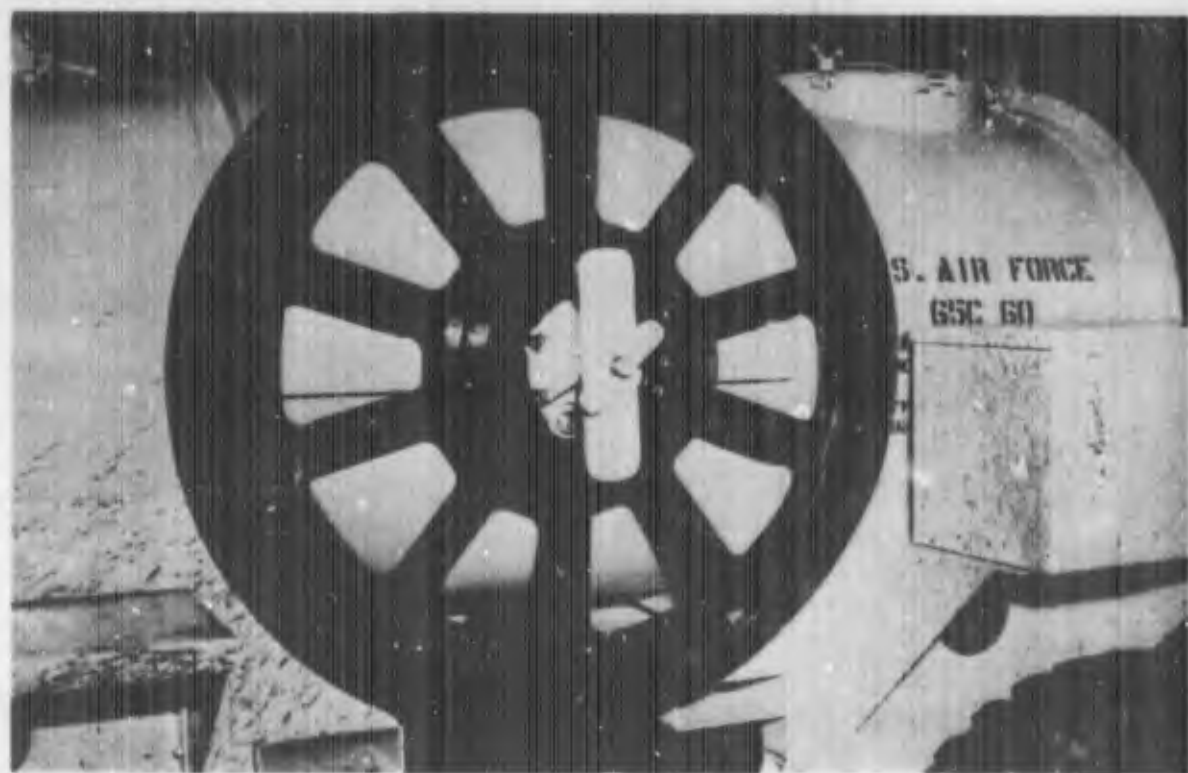


Figure 37. "Cookie Cutter" Disc Stowed on Resin Tank Trailer

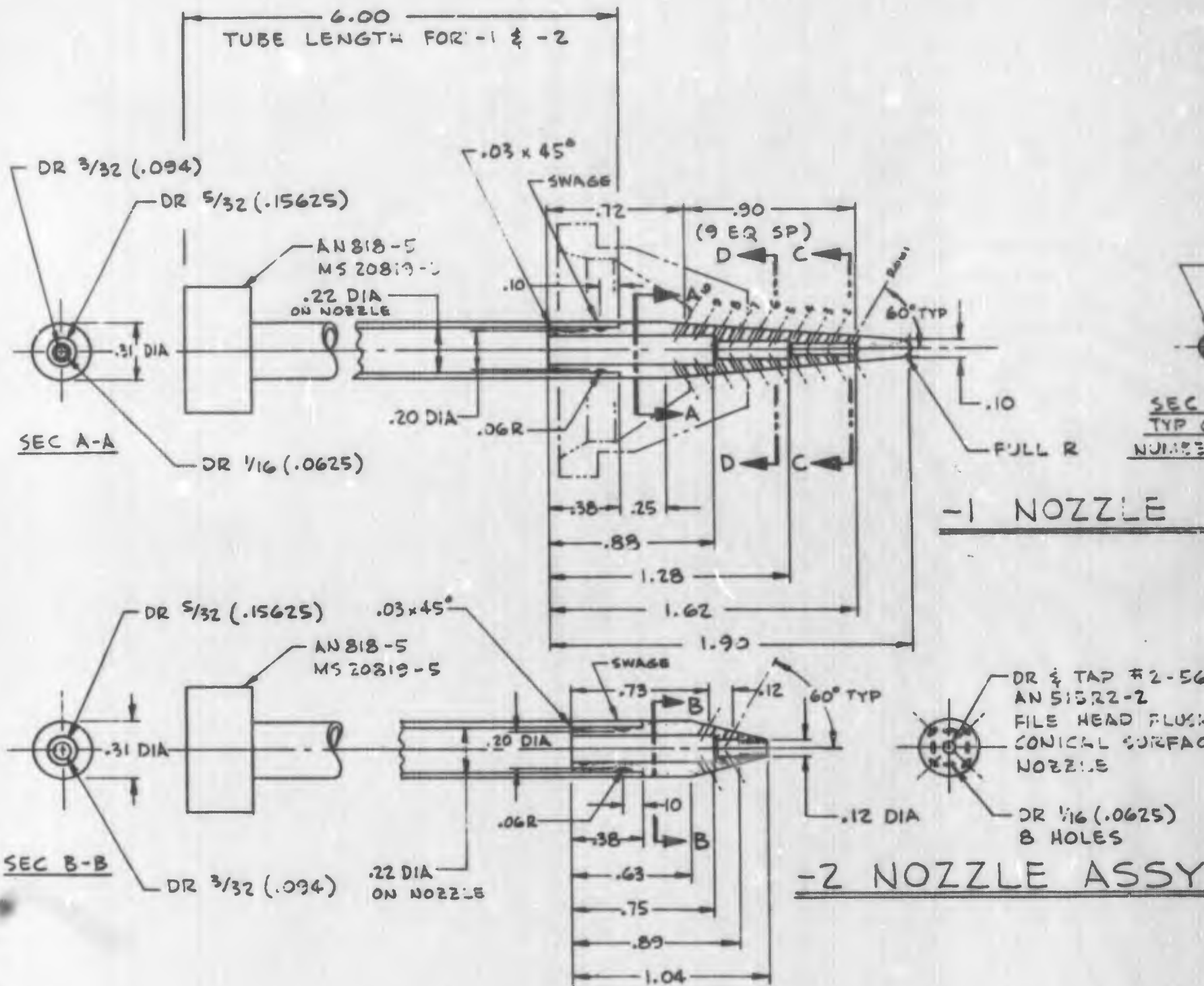
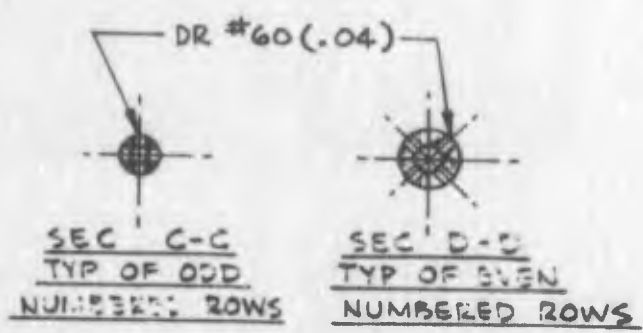
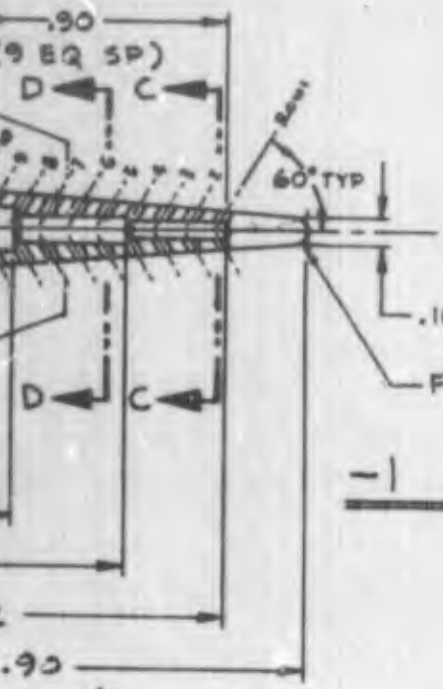


Figure 38. Catalyst Injector Nozzle

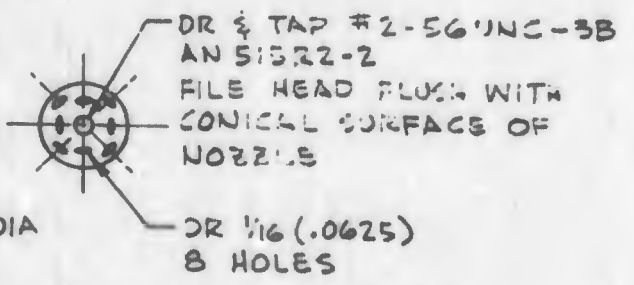
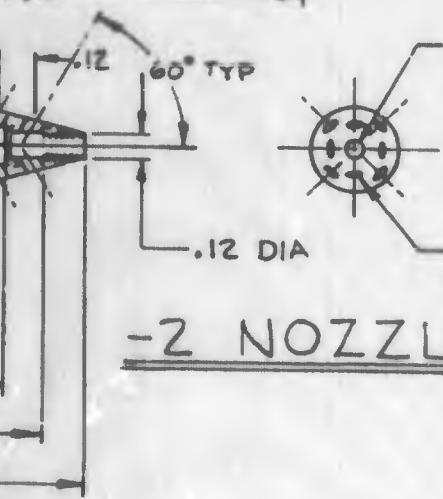
A



-1 NOZZLE ASSY

NOTES:

1. MACHINE NOZZLES FROM 7075-T6 ALUM BAR
2. BREAK SHARP EDGES
3. MAKE TUBE FROM 5/16 DIA x .035 WALL CRES 304 (OR EQUIV)
4. SEAL TUBE TO NOZZLE WITH EPOXY AT ASSY
5. FLARE TUBE PER MS 33584



-2 NOZZLE ASSY

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of the resin hoses, allowing the operator freer rotational movement of the pole gun (Figure 39). Secondly, a new spray head (Figures 39 and 40) was designed that set the spray nozzle at a more normal angle to the ground when in use. This was done to relieve the unnatural stance and grip required to use the earlier design. Finally, an effort was made to reduce the overall weight of the pole gun, and the associated operator effort required to move large resin hoses. The initial design of Figure 39 did not prove to be a weight saver for two reasons. First, the resin system flow evaluation, previously discussed in paragraph b, page 98, dictated the use of larger resin hoses than used in the pre-Europe design; and secondly, the use of two 1 1/2-inch swivel fittings plus the incorporation of a ball-type shut-off valve on the gun (Figure 39) resulted in a heavy design. The weight of resin in the hose and gun, added to this, resulted in excessive weight to be handled by the operator, particularly on warm days or for extended time intervals. This weight could be reduced by the elimination of one swivel fitting and the ball valve.

The second consideration for weight savings proved additionally rewarding. A one-inch tube, with one-inch swivel fittings, was adapted to the 1 1/2-inch spray head (Figure 41). To this, a 6 to 8-foot piece of one-inch hose was inserted before attachment to the main resin hose. This reduction in size, and the elimination of the ball valve, made a drastic savings in weight, and the unit performed satisfactorily during tests conducted at LTV under ambient temperatures of 65° to 85°F. Because of pressure drop in the lines, particularly at lower temperatures, the lightweight pole gun must be replaced by the larger, heavier unit when operating at temperatures lower than 65°F.

#### f. High-Pressure Glass Pot

Operations prior to and during the European tests revealed several fiberglass system deficiencies, as described in paragraph d, page 107 and several minor modifications were made to correct them. However, it was felt that an improved glass pot would be required to overcome two deficiencies inherent in the pre-Europe glass pot: permissible pressure and pot size.

During the post-Europe design program, the Archilithic Corporation demonstrated a commercial type of high-pressure glass pot which operated at 100 psi air pressure. This unit was also capable of use with 70-pound rolls of continuous roving fiberglass, up to 120 end roving. Laboratory tests showed that the unit could spray glass through hoses up to 60 feet long, without the malfunctions experienced with the low pressure (30 psi) pre-Europe system.

This demonstration unit, however, was constructed of steel, and weighed approximately 180 pounds empty. Preliminary design recommendations were made for an aluminum unit.

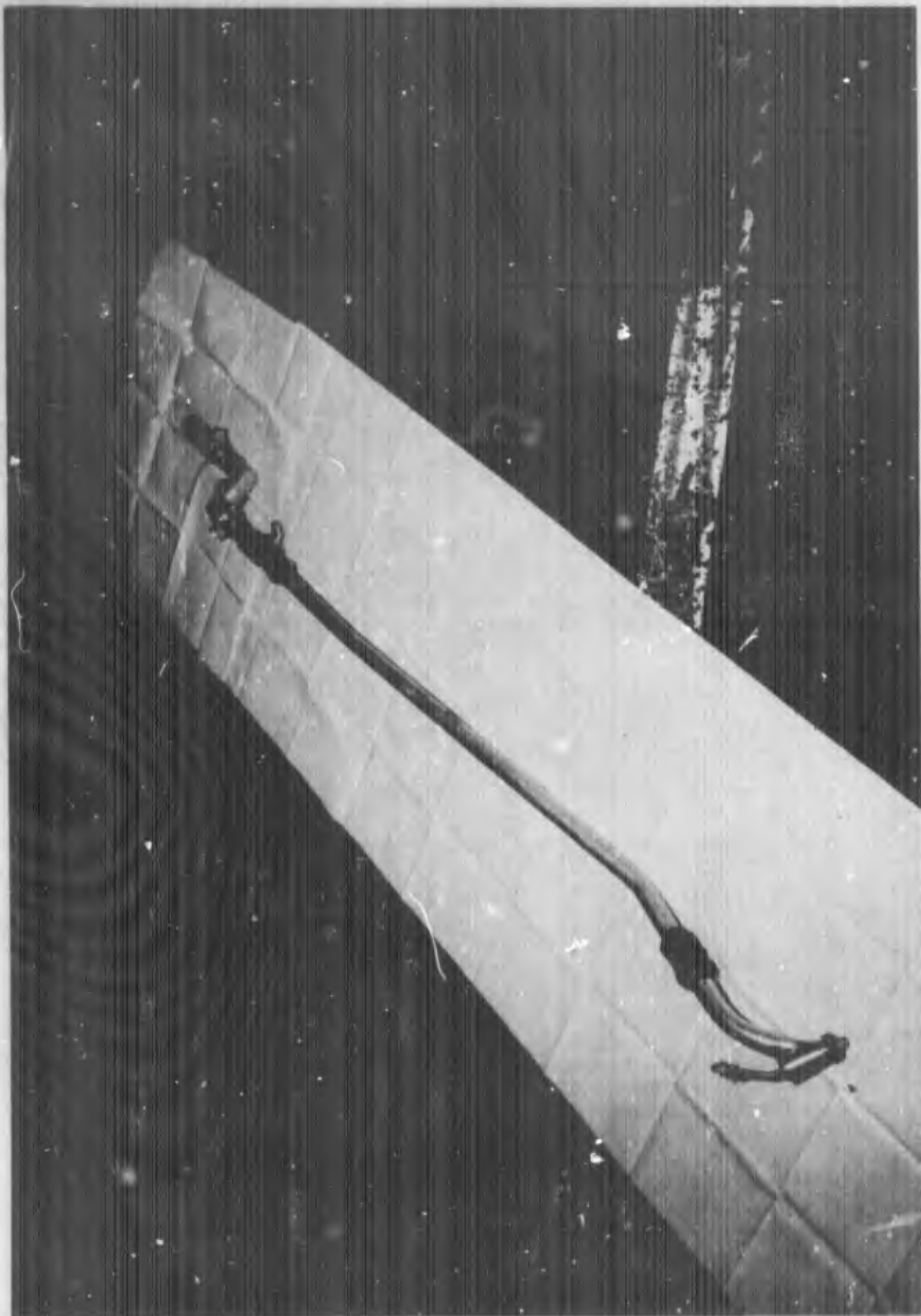
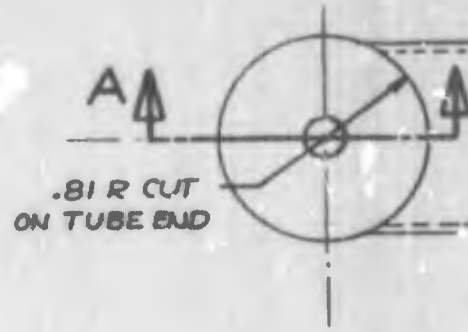
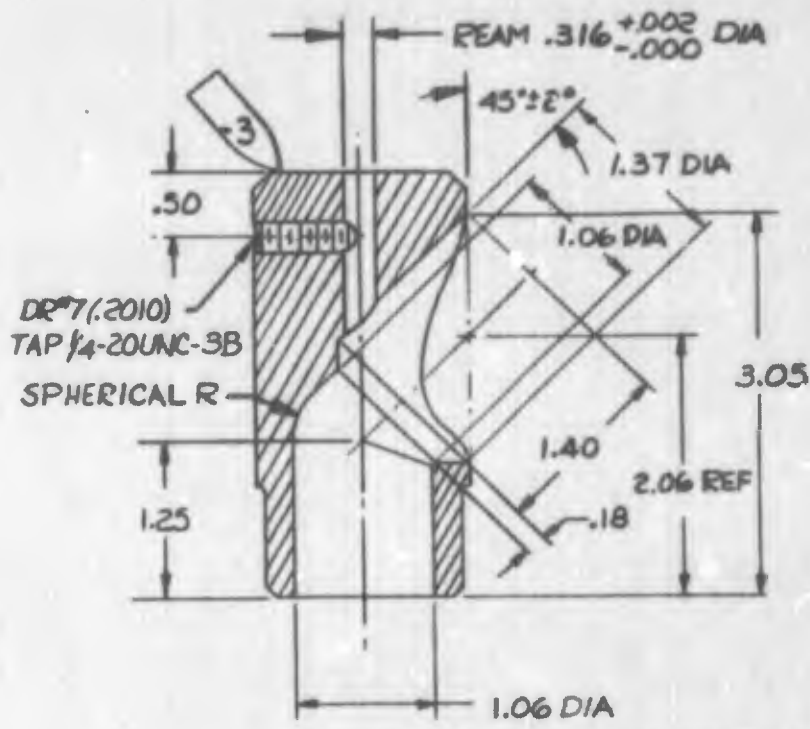


Figure 39. Pole Gun - 1 1/2-Inch Tube - Post-Europe

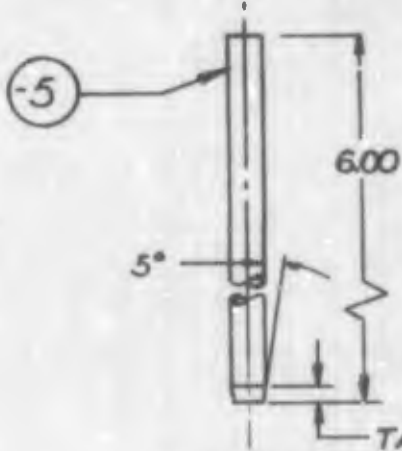
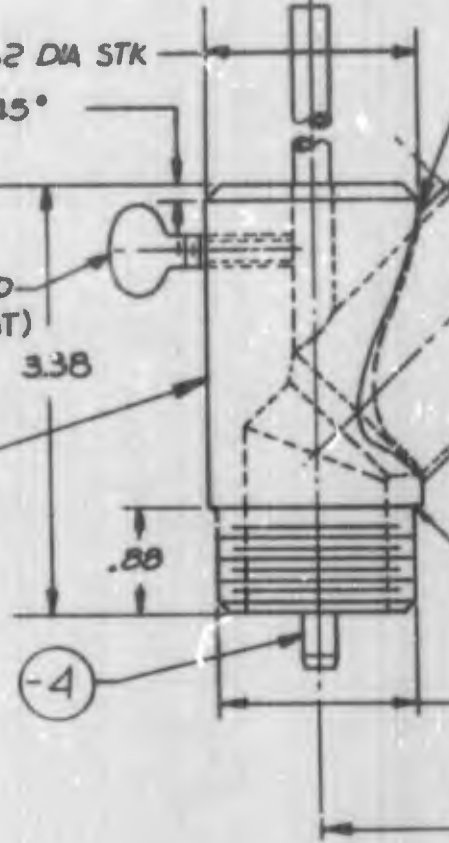


SECT A-A

MS 21317-44 ~1REQD  
(OR COMML EQUIVALENT)

1.62 DIA STK  
.12 x 45°

(-3)  
MATL-6061-T6



-4 CATALYST TUBE-1 REQD

-5  
MATL: CRES 304 (MILT 6845)  
5/16 OD x .065 WALL

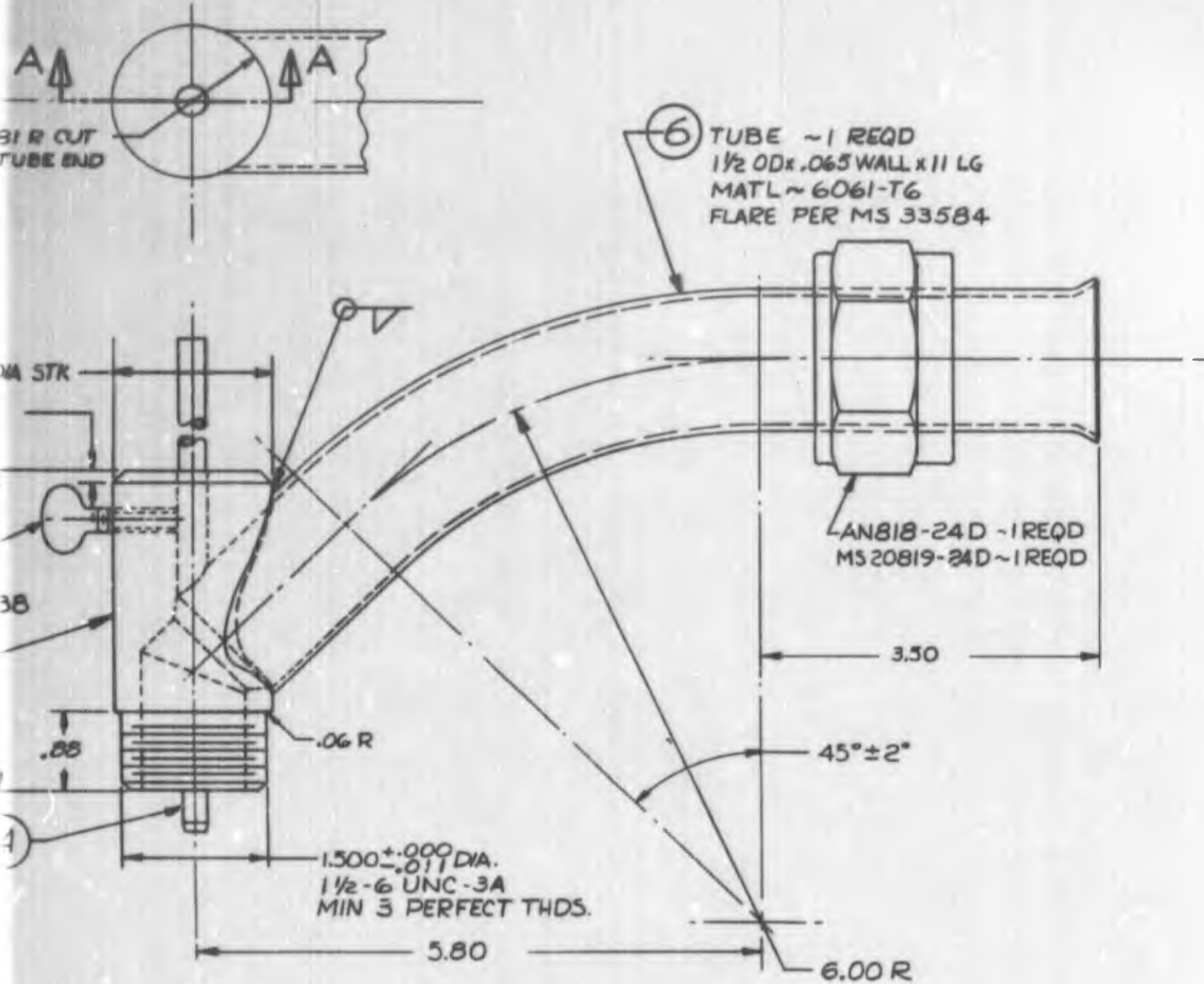
CANCELLED

-2 SPR

- NOTES:
1. SPRAY HEAD FM CAP & FOR TEST
  2. BREAK SH
  3. MATL EO'S
  4. TOLERANCES

Figure 40. Pole Gun - Post-Europe

A



-2 SPRAY HEAD

NOTES:

1. SPRAY HEAD TO UTILIZE FM CAP & NOZZLES FOR TESTS
2. BREAK SHARP EDGES
3. MATL EO'S 10038.6 & 10038.10
4. TOLERANCES - UNLESS NOTED: ±.01

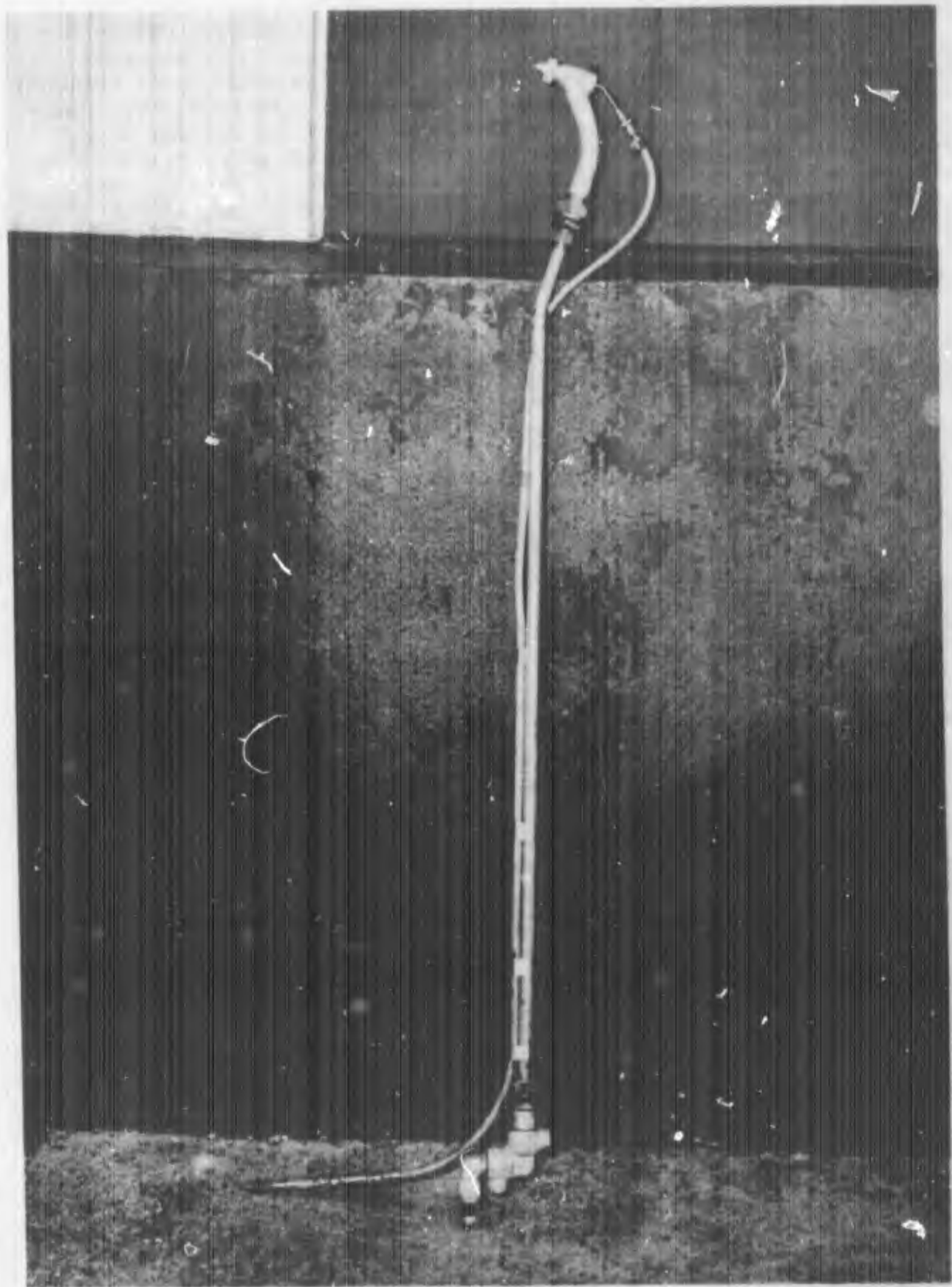


Figure 41. Pole Gun - 1-Inch Tube - Post-Europe

Figures 42 and 43 show the preliminary glass pot design furnished to the Archilithic Corporation by LTV. The shell is a rolled aluminum shell with a deep drawn bottom. The lid is built up of aluminum plate to provide a hinged attachment to the shell. The overcenter cam-type latch bar is provided with an interlock to prevent opening of the lid until the air pressure hose is disconnected. The glass roll will be inserted into the pot from the top with a pail. Other features, such as handles, glass hose connections, relief valve, pressure gage and a bail for guiding the glass within the pot, will be similar to the pre-Europe configuration. Use of this type of pot will eliminate the use of the fiberboard glass container as a part of the pressure vessel.

Construction of a single unit was subcontracted by Archilithic late in the Phase I program, but material shortages delayed its completion. Testing of the single unit will be conducted by LTV during Phase II.

#### g. Tank Trailer Improvement

Several improvement modifications were incorporated on the resin tank trailer. Two storage support shelves were added on the right-hand side (Figure 44) and a full length shelf replaced the small shelf on the forward left-hand side (Figure 45). Three storage boxes were added to the full length shelf. The catalyst container was mounted on the forward right-hand shelf (Figure 44), and the remaining shelf was left open for possible future use. Because of problems encountered in unloading the fiberglass containers, the original container (Figure 12) was replaced by a container which had a full height, fully removable cover (Figure 44). This container required modified support shelves on the front and rear ends of the tank trailer to support the container base (Figure 46).

During the European operations, a gradual settling was observed in the forward springs. This problem was reviewed with the supplier of the running gear, and resolved by the installation of front spring kits to increase the spring rate and total capacity.

Trailer brake wiring, improperly installed prior to the European tests, was reworked to provide correct braking action. "Curly cords" and larger connectors were added to the tank trailer wiring to improve operations and reduce connector damage. These are shown in Figure 45.

To reduce the inherent difficulty of mounting the soil disc on the tank trailer with five bolts, a new disc mount was designed, using a single wing nut type of attachment to hold the soil disc, Figure 37. The mount also provides for storage of the bolts used to attach the disc to the prime mover wheel.

Major tank trailer modification design was initiated to provide added handling and shipping features. The first of these was the design and installation of a hoist beam, Figures 47 and 48, capable of

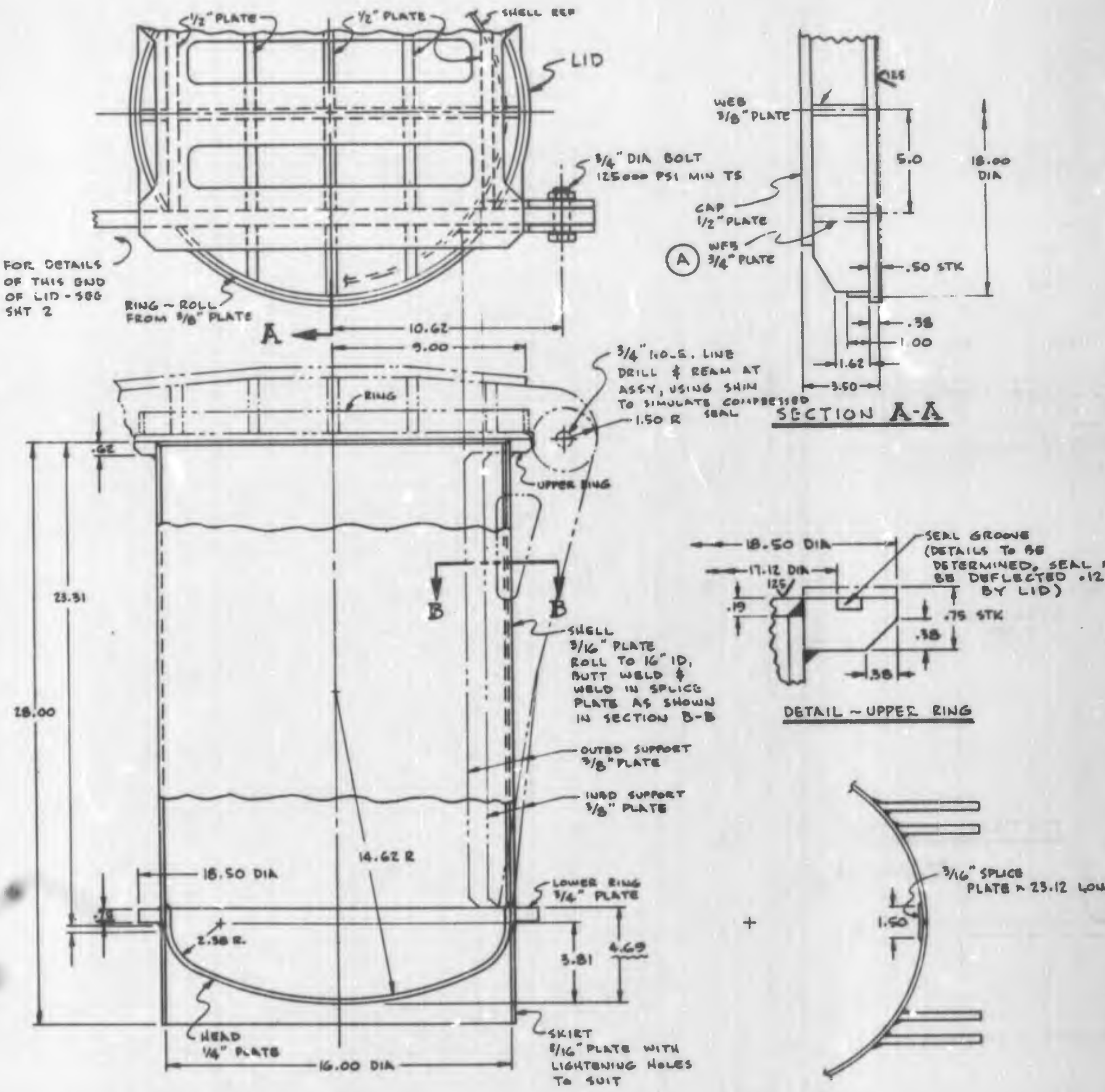
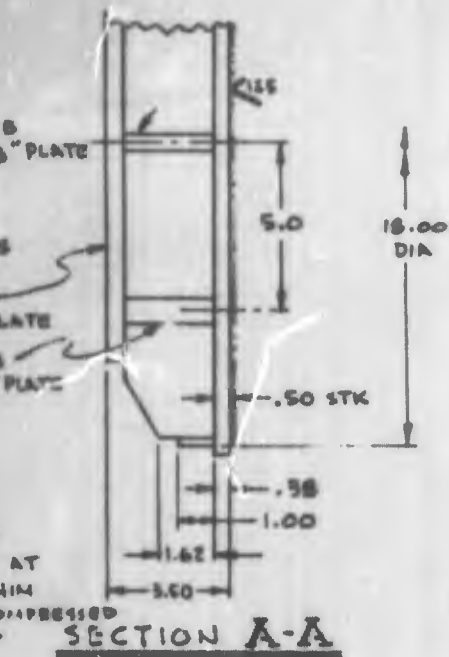


Figure 42. High Pressure Glass Pot - 100-psi

A



**NOTES:**

1. THIS DRAWING DEFINES OVERALL SIZE, SHAPE, & APPROXIMATE MATERIAL THICKNESSES FOR A GLASS POT TO BE OPERATED AT 100 PSIG. MATERIAL SELECTION, THICKNESSES, & JOINT DETAILS ARE IN GENERAL ACCORD WITH RECOMMENDATIONS OF THE ASME BOILER & PRESSURE VESSEL CODE, SECTION VIII, 1965 EDITION. THIS DRAWING IS NOT A DETAIL DESIGN, NOR DOES IT REFLECT A COMPLETE ANALYSIS OF STRESSES, JOINT DETAILS, ETC.

2. RECOMMENDED MATL: 6061-T6 ALUM PLATE, SPEC SB-209. ALL WELDS 100%.

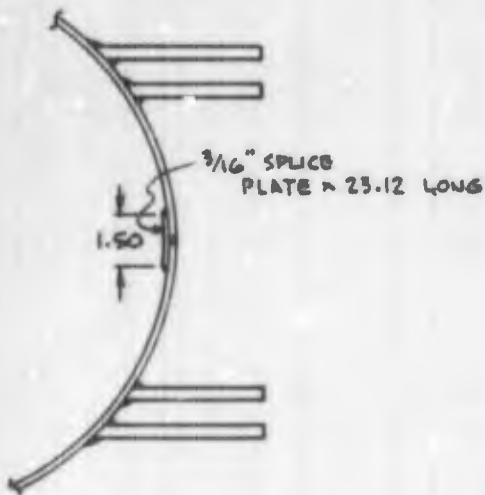
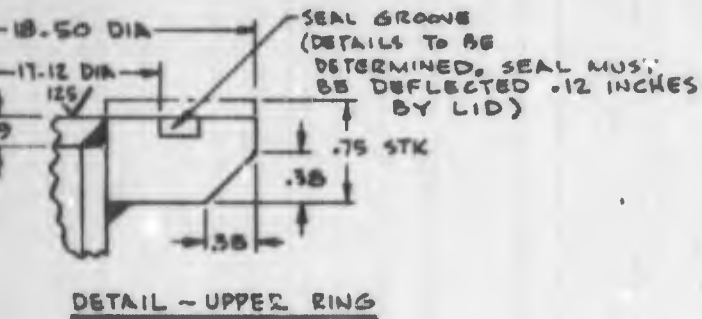
3. PRESSURE TEST TO 150 PSIG IN ACCORD WITH REQS OF ASME CODE

4. FEATURES REQD BUT NOT DETAILED

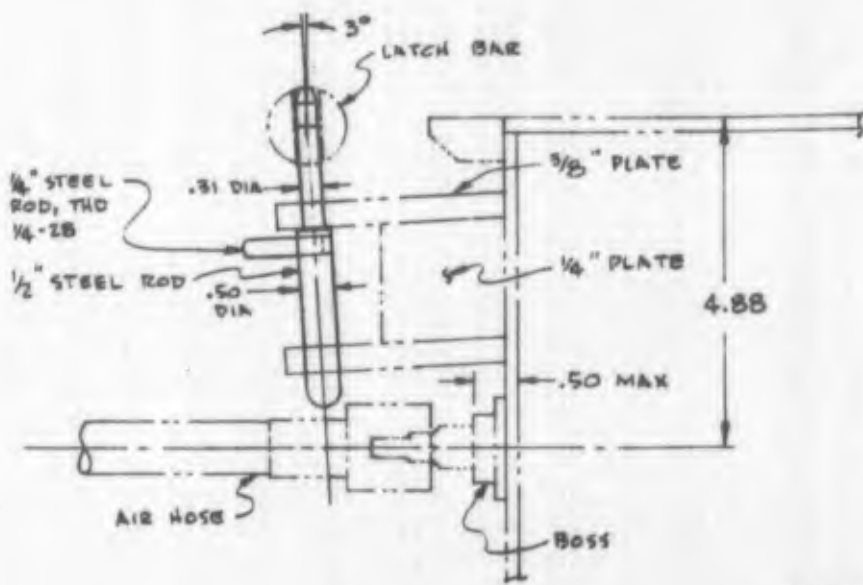
- AIR INLET BOSS - 3/8" FPT
  - RELIEF VALVE BOSS - 1/2" FPT
  - GLASS OUTLET BOSS - 3/8" FPT
  - CARRYING HANDLE - 2 REQD
  - GLASS ROLL CONTAINER & SUPPORT PROVISION
  - BAIL WIRE OR EQUIVALENT
- } SEE ASME CODE FOR RECOMMENDED DESIGNS

5. ESTIMATED WEIGHT BREAKDOWN:

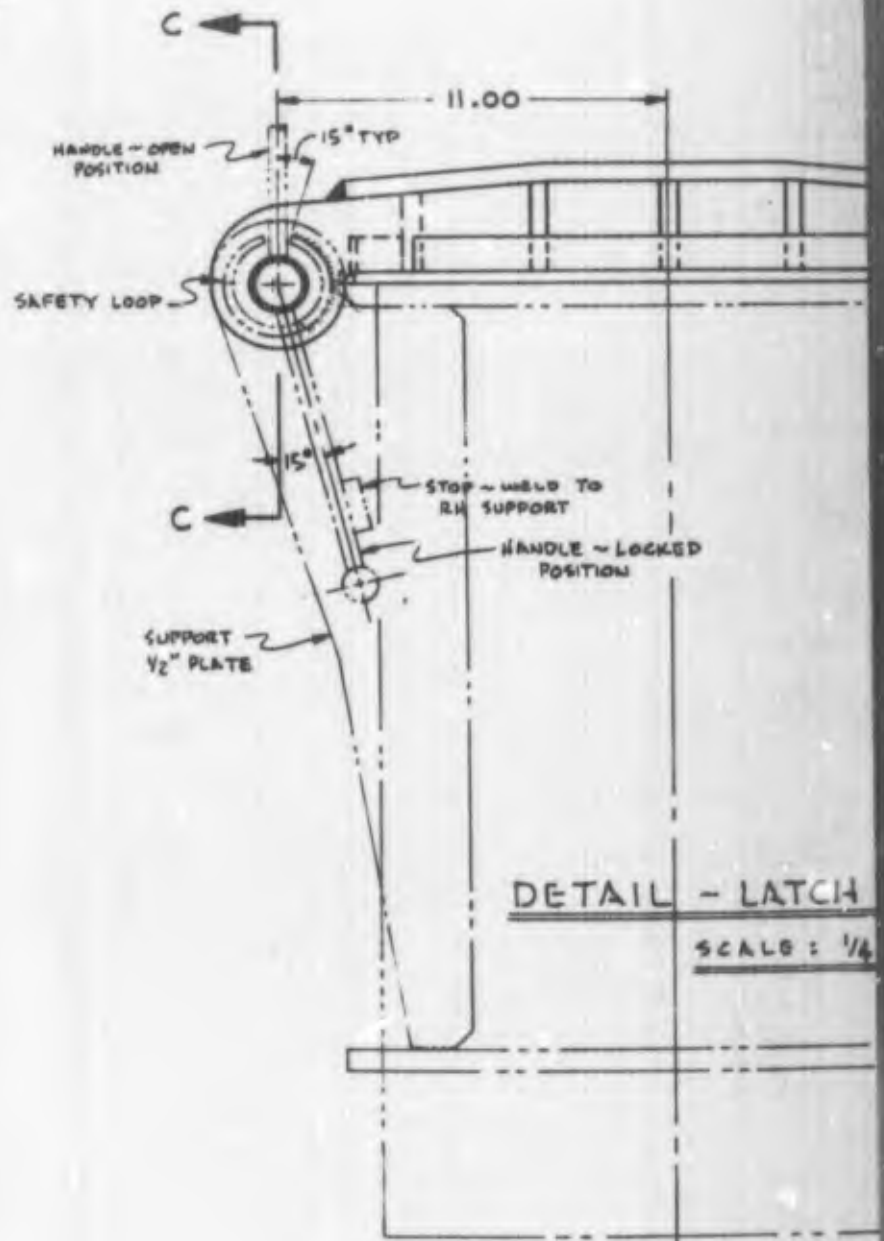
LID	---	---	---	---	---	35	LBS
SHELL	---	---	---	---	---	22	
SKIRT (25% LIGHTENING HOLE AREA)	---	---	---	---	---	3	
HEAD	---	---	---	---	---	8	
LOWER RING	---	---	---	---	---	4	
UPPER RING	---	---	---	---	---	4	
SUPPORTS	---	---	---	---	---	11	
MISC	---	---	---	---	---	5	
TOTAL	---	---	---	---	---	92	LBS



B



SECTION D-D  
SCALE: 1/2  
(SHOWS SAFETY INTERLOCK)



DETAIL - LATCH  
SCALE: 1/4

A

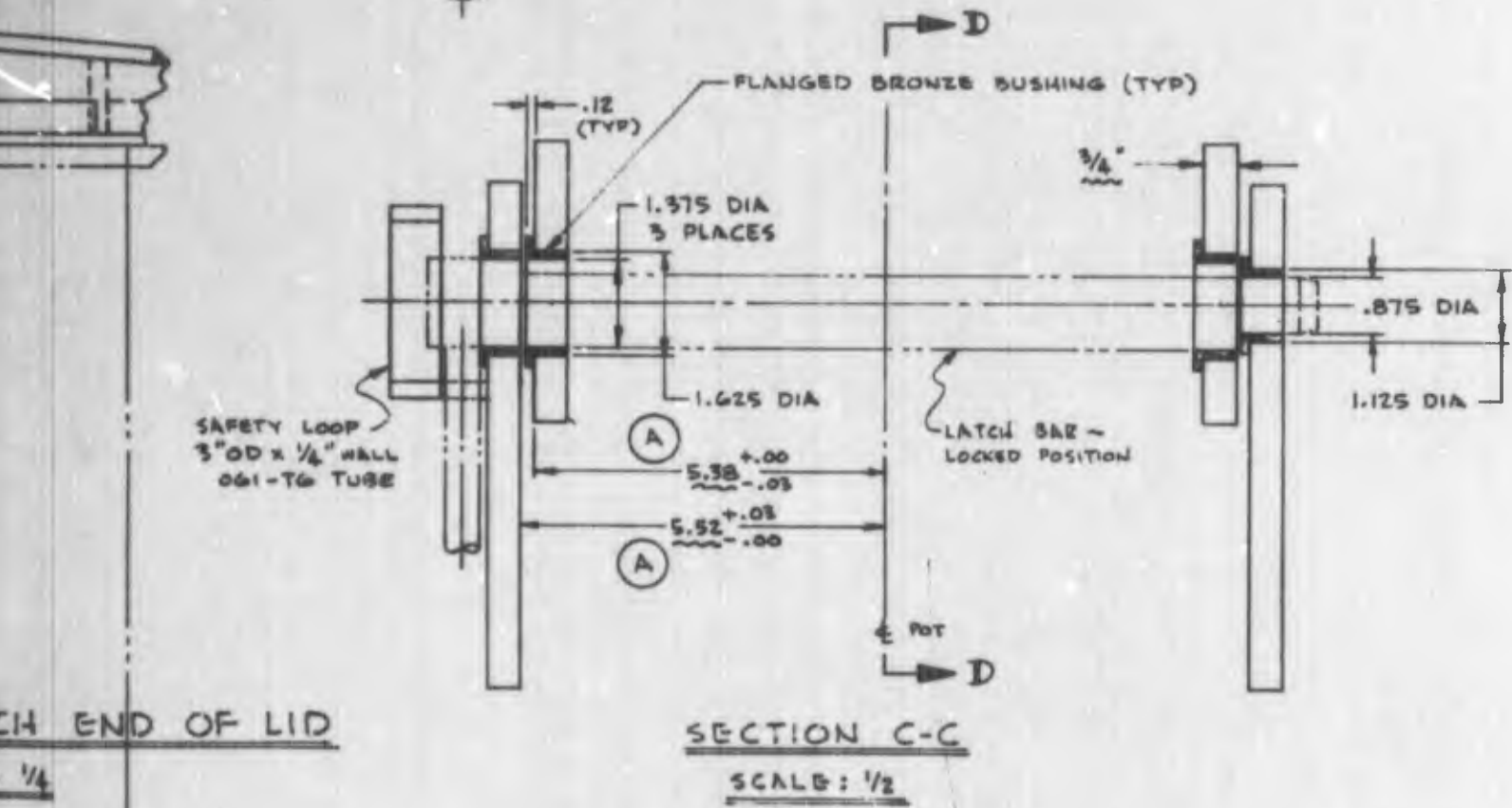
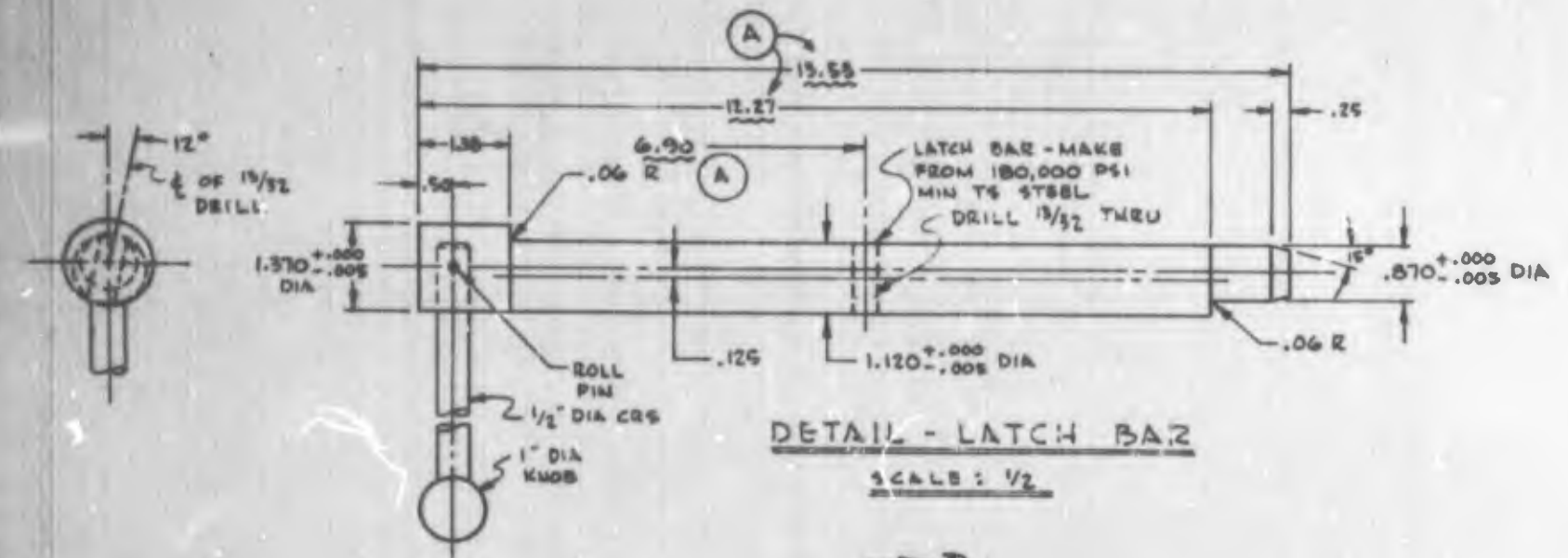


Figure 43. High Pressure Glass Pot - 100-psi

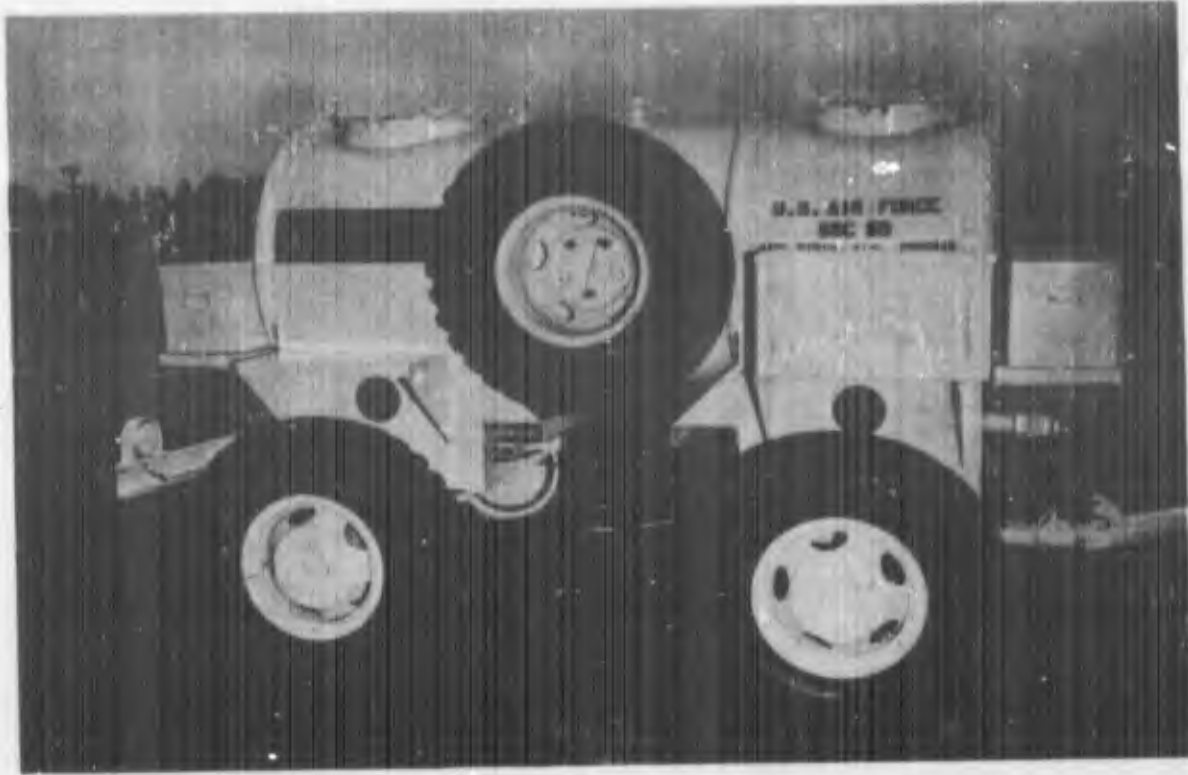
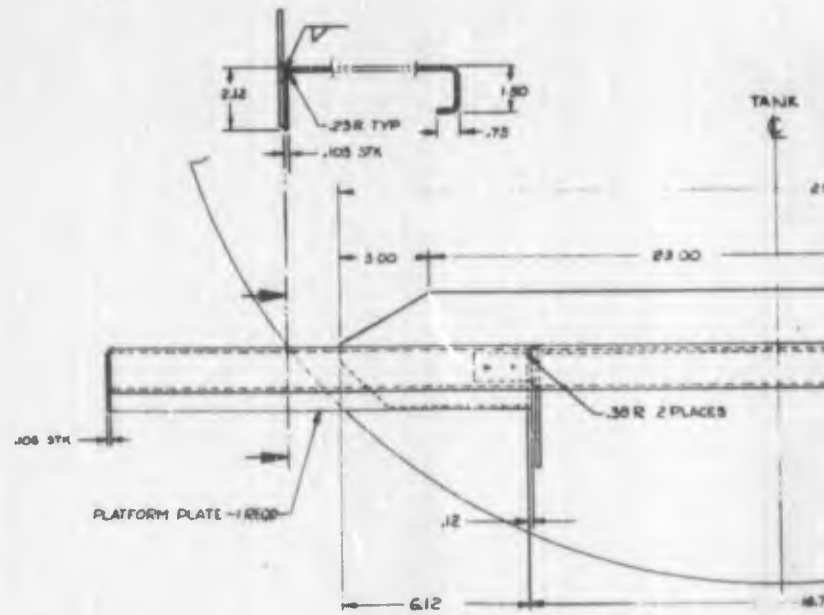
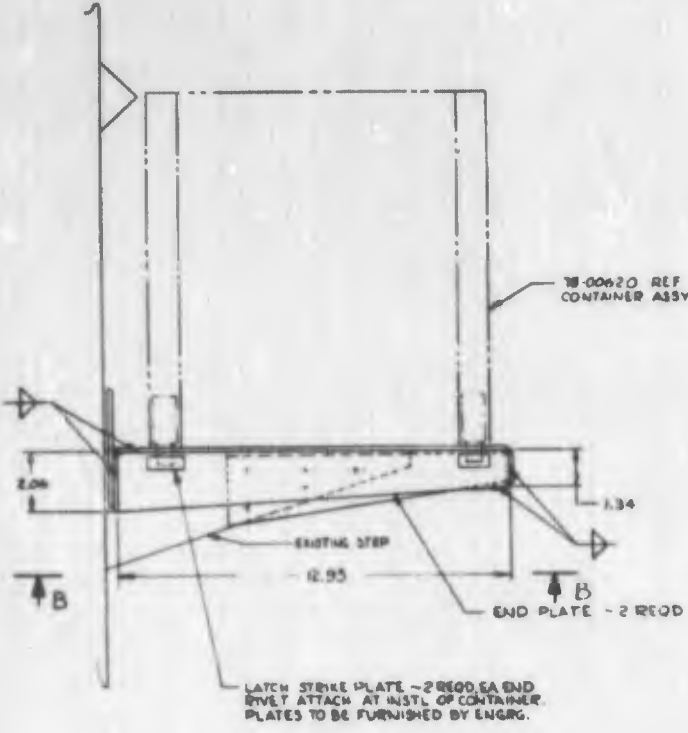
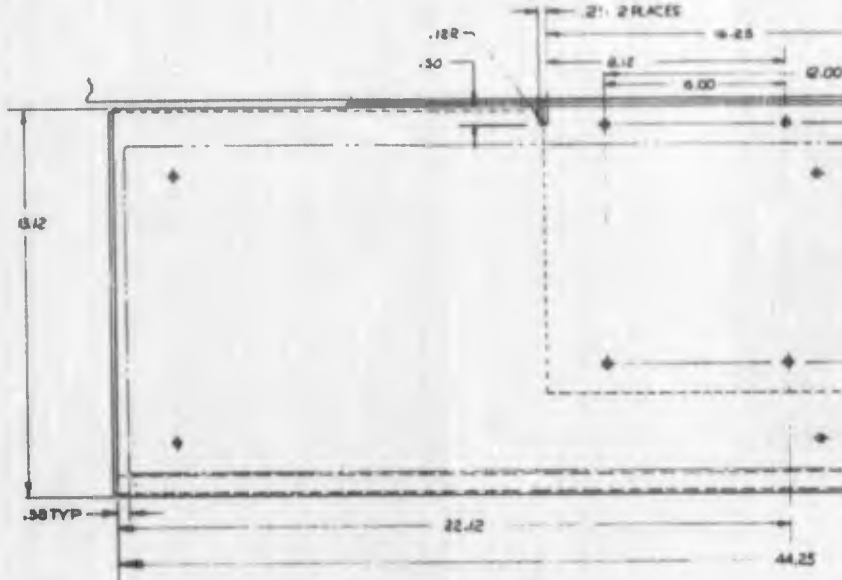
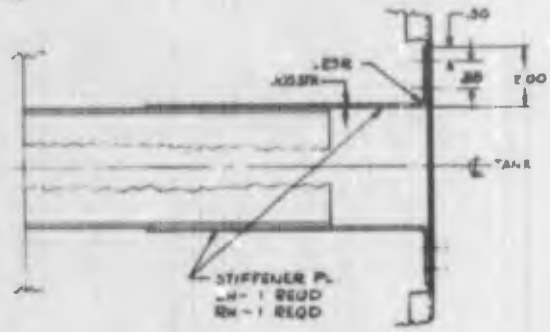
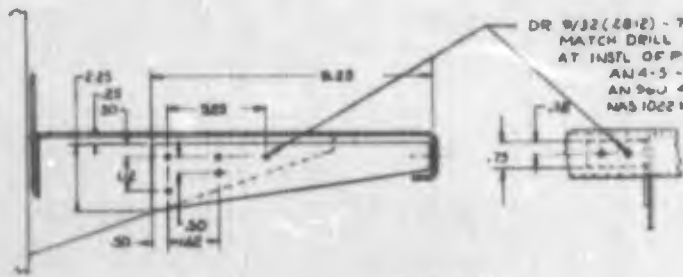


Figure 44. Resin Tank Trailer Assembly - RH Side

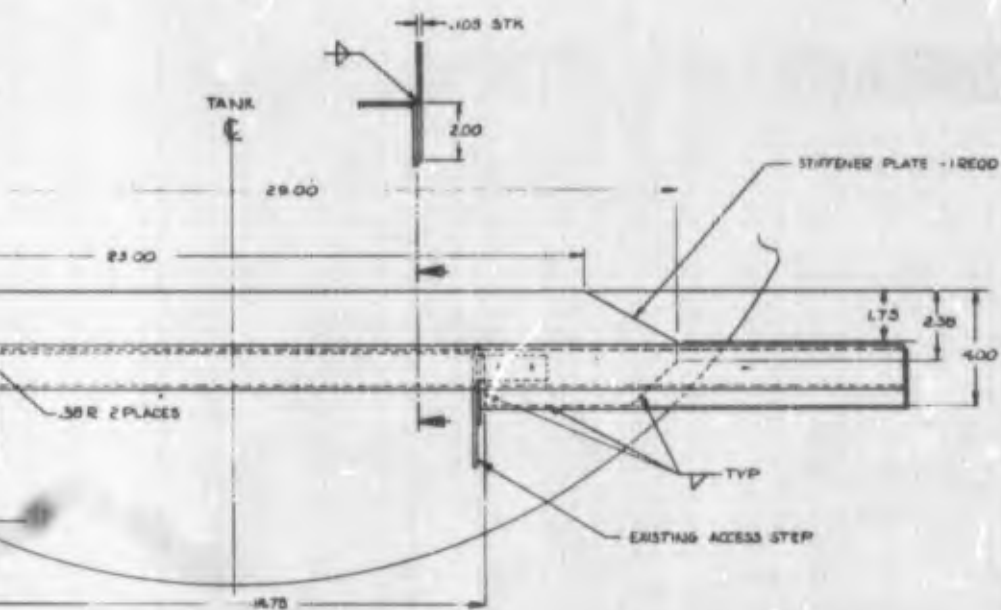
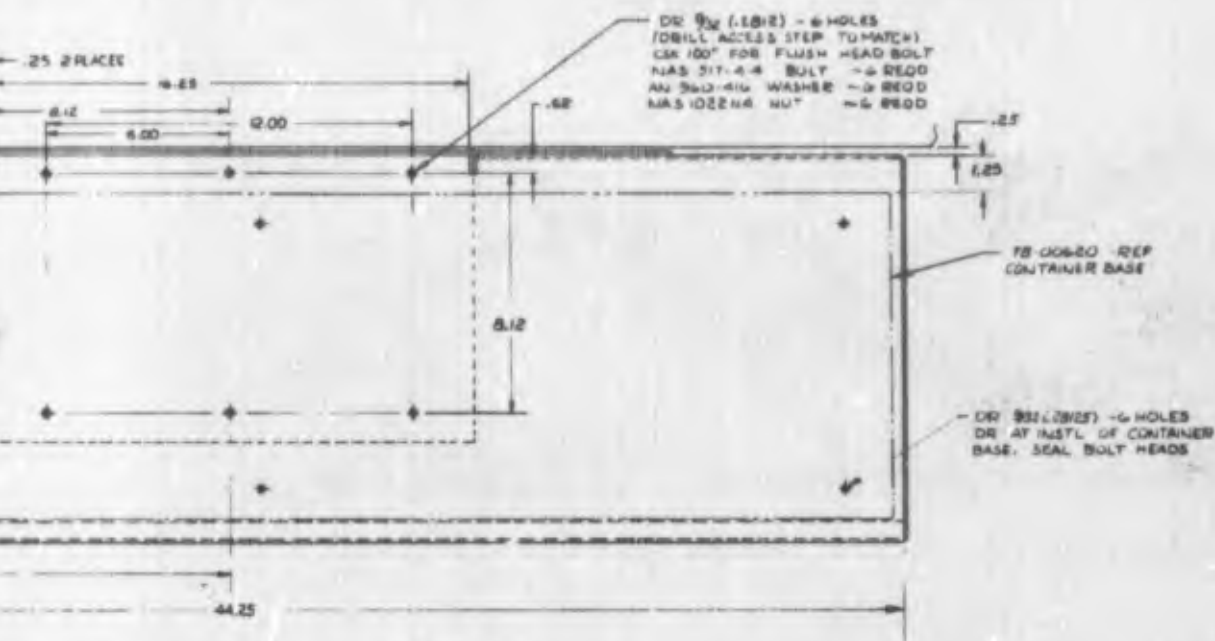


Figure 45. Resin Tank Trailer 3/4 View



SUPPORT ASSY  
 SCALE  
 2 REQD

A



- NOTES:
1. MOD TO PROVIDE SUPPORT FOR NEW FIBRE GLASS CONTAINER (78-00-201)
  2. MATL: 1/2" (1/4") ASTM-A151 STL
  3. MATL PURCHASED ON ED 100374 (RIVETS NOT INCLUDED)

SUPPORT ASSY - FIBRE GLASS CONTAINER  
 SCALE  $\frac{1}{2}$   
 2 REQD (1 EA END)

Figure 46. Support Shelf Modification Fiberglass Boxes

B

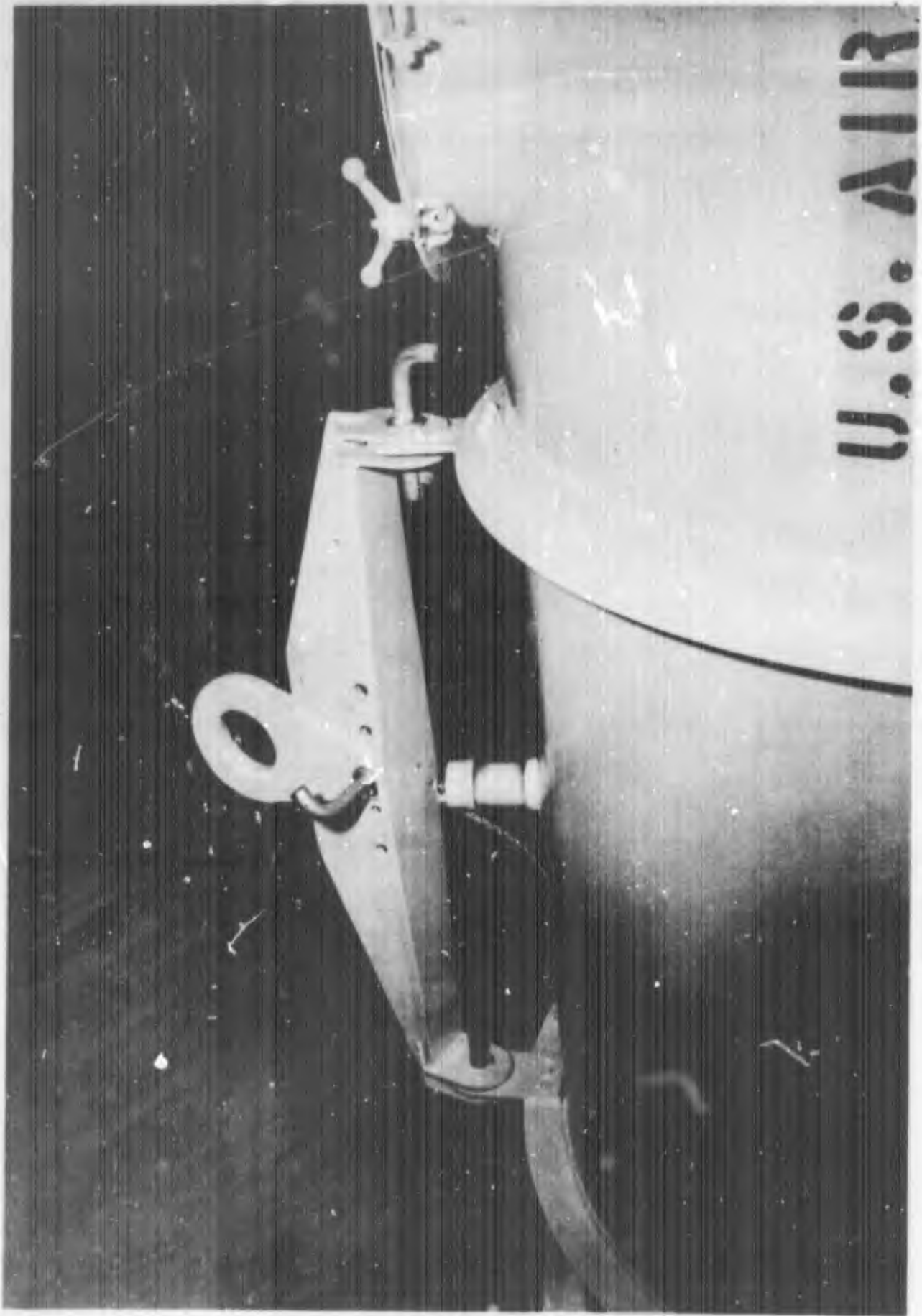


Figure 47. Tank Trailer Hoist Beam

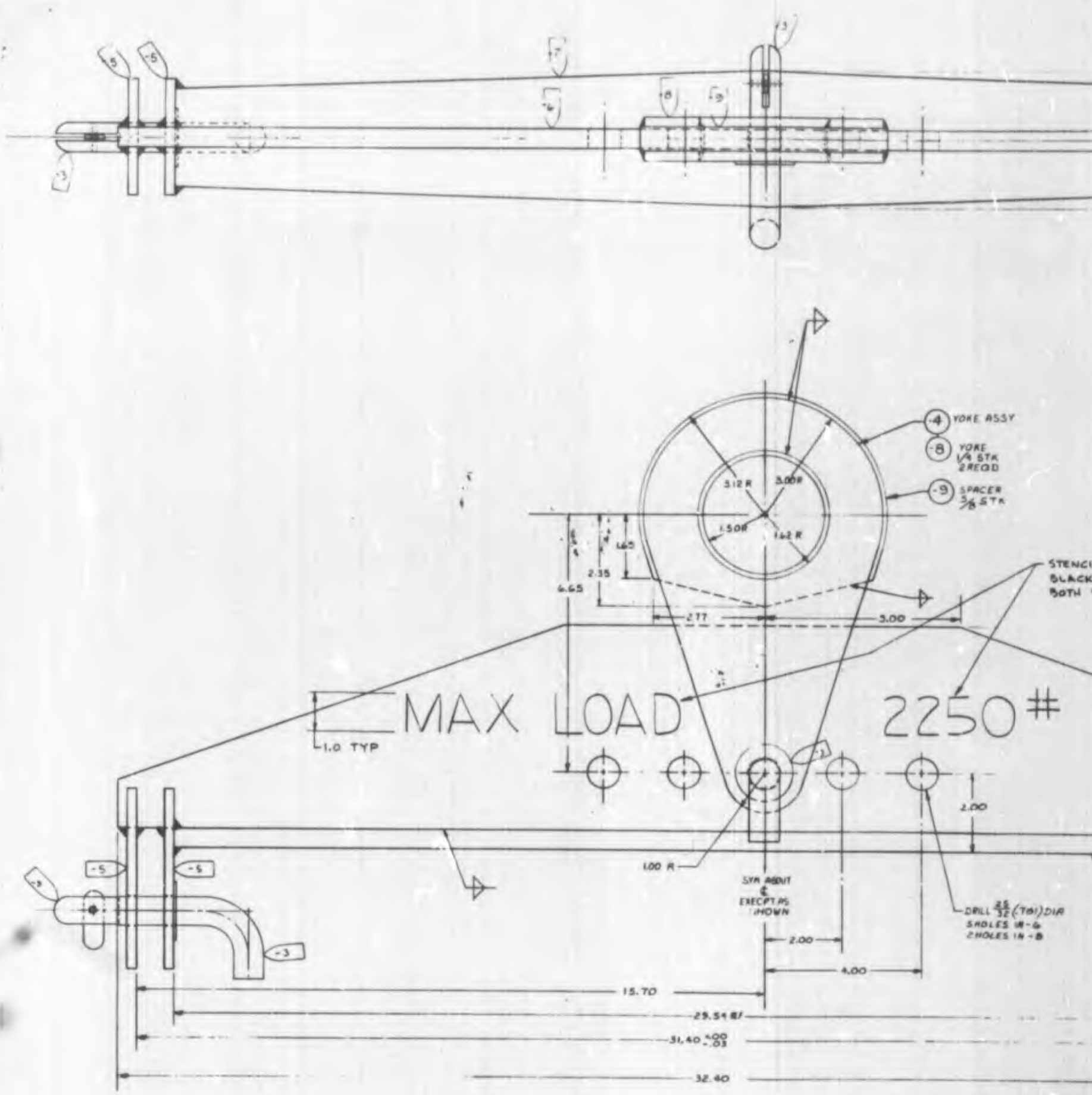
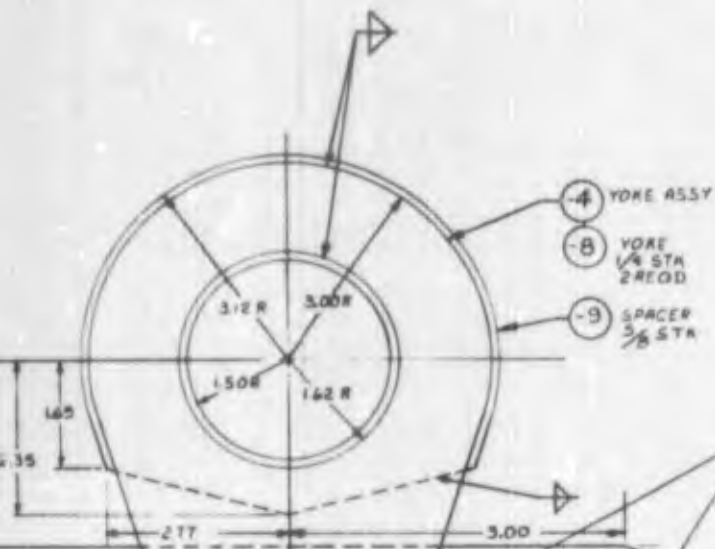
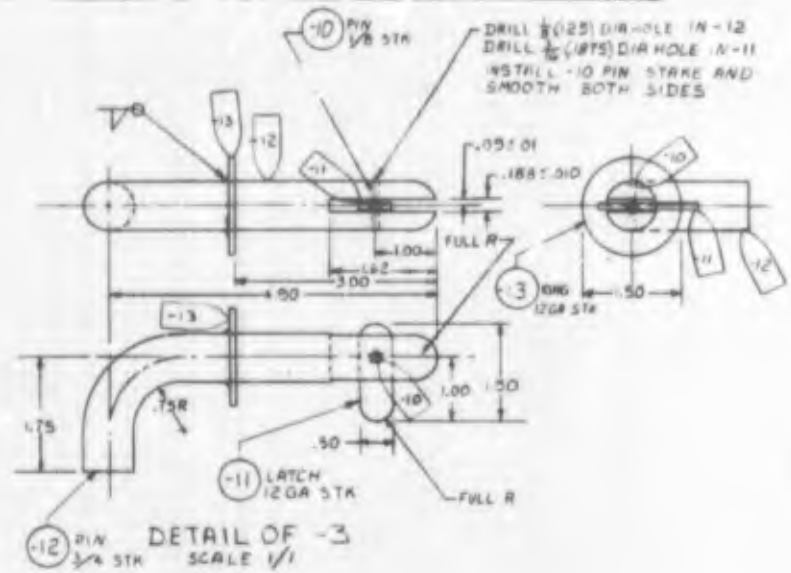
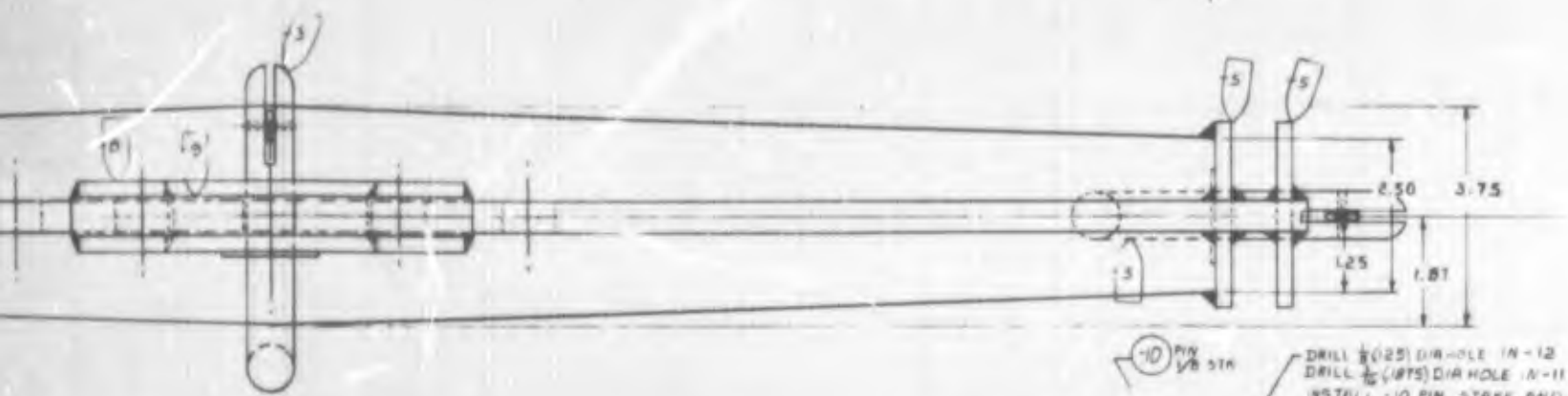


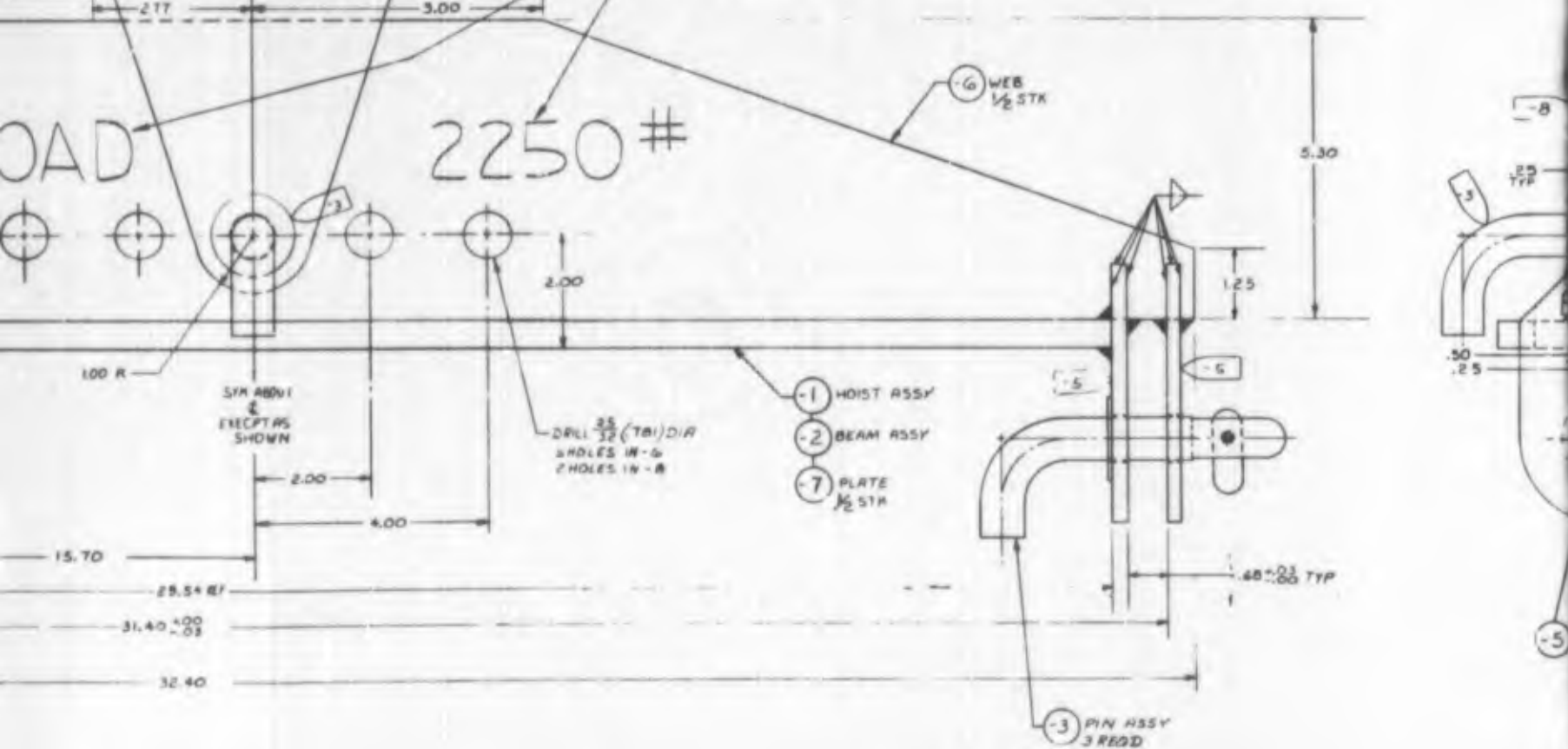
Figure 48. Hoist Beam - Tank Trailer

A

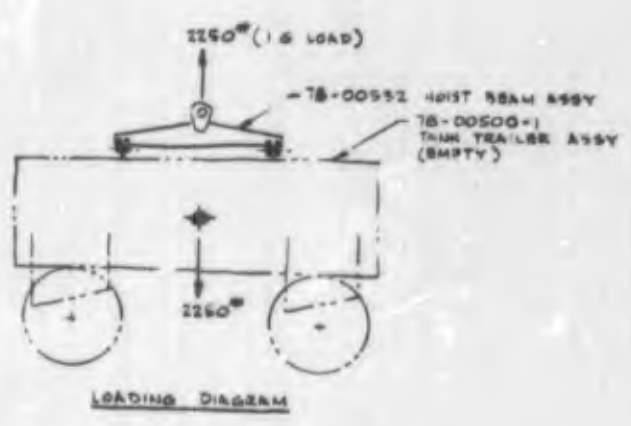
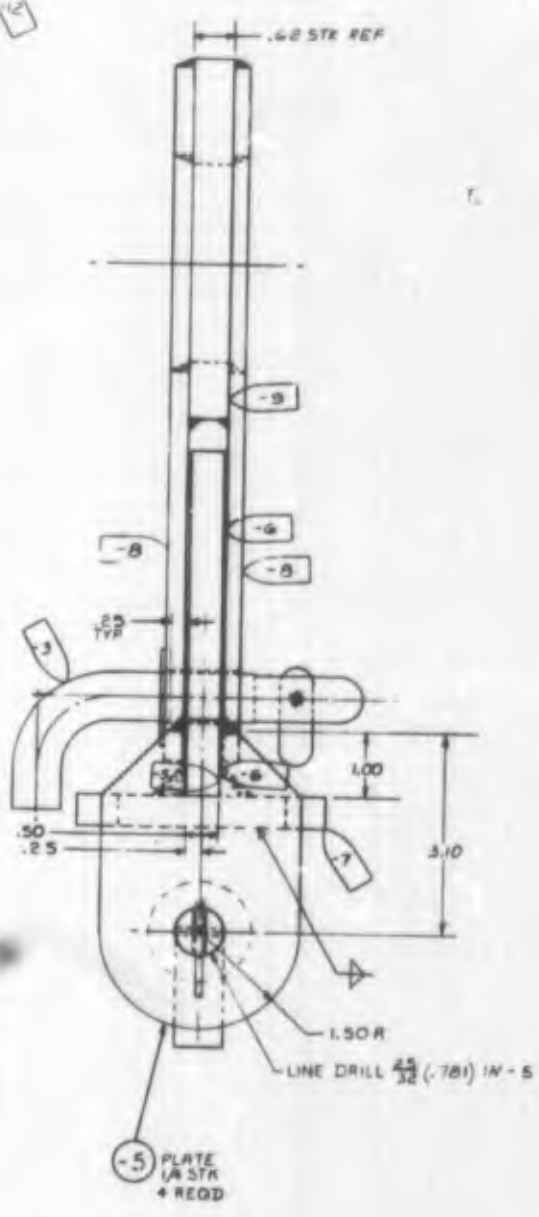


STENCIL  
BLACK ENAMEL  
BOTH SIDES OF -2

2250 #



-12  
-11  
AND



NOTES:

1. BREAK SHARP EDGES
2. PROOF LOAD BY LIFTING A 4500# SIMULATED TRUCK TRAILER. THE SIMULATION SHALL INCLUDE HOISTING PLATES IDENTICAL TO THOSE SHOWN ON 78-00501, SHT. 2

C

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lifting an empty trailer weighing 2250 pounds. The beam design was in accordance with the requirements of MIL-S-8512B. A second handling improvement was the addition of forklift tubes with a tiedown ring attached to each tube, Figure 49. The forklift tubes and tiedown rings were also designed for handling an empty trailer. A shipping skid to be used for future air shipments or shipments that require removal of the trailer wheels was also designed and four units fabricated, as shown in Figure 50.

#### h. Portable Resin Transfer Pump

The Rapid Site application equipment was originally designed to support fabrication of sites using no more than 1400 gallons of resin. To transport this resin, and to supply it to the prime mover during spray operations, four tank trailers, each holding 400 gallons of resin, were provided. However during the latter part of Phase I, revised Air Force plans indicated a need to fabricate larger sites. Analysis of site construction techniques showed that in order to sustain continuous spraying operations refilling of the tank trailers would be required approximately every forty minutes after the four trailers of resin were consumed. Rather than purchase additional tank trailers and because the tank refill area might be distant from the landing site, a portable resin transfer pump was designated and fabricated.

In addition to its use as a tank refill pump, the transfer pump will be used during Phase II as a test bed for miscellaneous subsystems, such as promoter injection and catalyst pumping.

The portable resin transfer pump was designed to meet the following requirements:

Readily movable, in rough terrain or on improved roads, on a trailer.

Road speeds up to 40 miles per hour on improved roads.

Road brakes and parking brakes required.

Assuming a resin specific weight of 11 pounds per gallon, viscosity of 5000 cps at 40°F and 21,500 cps at 74°F, pump shall be capable of pumping resin at 12 to 27 gallons per minute, respectively, at 200 psi.

Shall be self-powered, not dependent on external power sources, with a gasoline engine.

Structure shall be bolted (rather than welded) to allow for future structural changes with minimum rework time.

Speed reduction from engine to pump shall be accomplished with belt systems to allow for future pump changes.

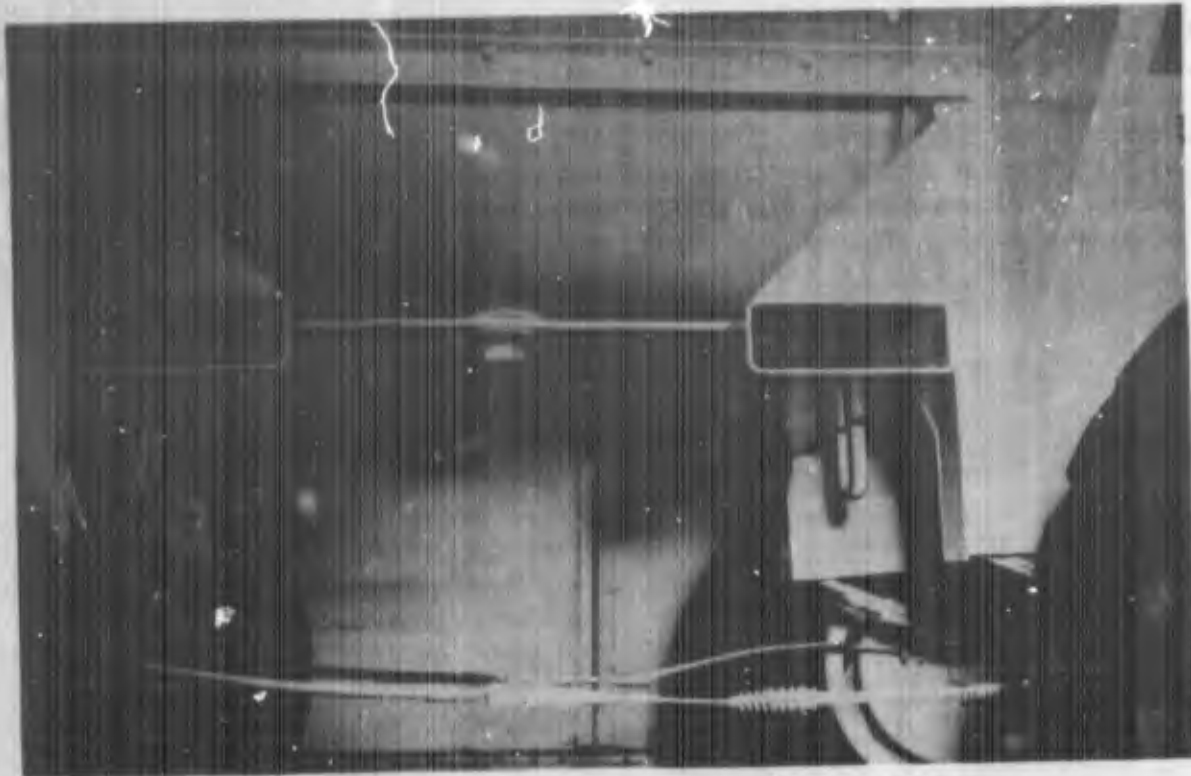


Figure 49. Fork Lift and Tiedown Provisions - Tank Trailer

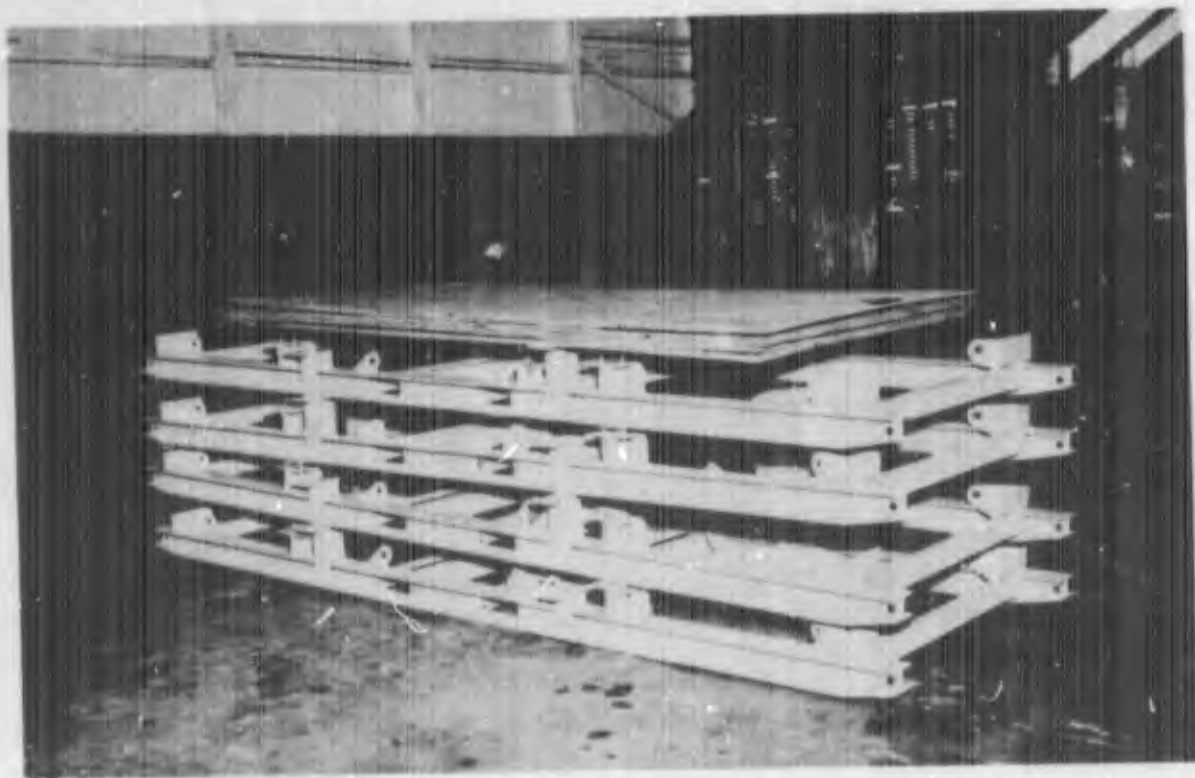


Figure 50. Tank Trailer Shipping Skids

System shall provide for future doubling of pump horsepower (through pressure of flow rate increases).

Figures 51 and 52 show the portable transfer pump partially complete and unpainted. The structure on which the system components are mounted permits lifting or hoisting with forklifts or overhead hoists as desired. The unit is driven with an air cooled Kohler Model K662, 2-cylinder, four-cycle gasoline engine. This engine will provide 24 hp at 3600 rpm and 15 hp at 1800 rpm. The engine includes a 5 1/2-gallon fuel tank, starter, generator, engine speed governor, and necessary gages and controls. Maximum horsepower required to drive the resin pump (27 gallons per minute, 200 psi, resin viscosity 5000 cps) is only 6, but the large engine was used to provide for future growth.

Running gear for the system is a four-wheel commercial trailer with brakes on the rear wheels only. It is capable of being towed on the highway at speeds up to 40 miles per hour. The primary brake system is an inertia operated unit with the master cylinder mounted in the tow bar. Parking brakes are manually operated with a lever mounted on the tow bar. The primary brake system includes automatic backup and breakaway provisions.

Driving power from the engine to the pump is transmitted through a compound belt transmission and two timing-belt drives (Figure 53). The transmission, similar to the unit used in the prime mover resin pump drive, provides a 5:1 variation in pump rpm, from 98 to 490. This is accomplished while the system is running by turning the large knob on the engine mounted half of the transmission. This in turn changes the pitch diameter of the pulley. Pitch diameter of the driven half of the transmission is accomplished automatically. On-off control of the resin pump is provided by the manually operated clutch between the engine and the transmission.

The combination belt cover and platform over the drive system provides both safety protection and storage space for miscellaneous equipment, and hoses.

Other features of the transfer pump include the suction and discharge hoses, a special tube attached to the suction hose for insertion into the resin drums, and the high pressure flow meter installed in the discharge line. This unit, capable of operation at 500 psi, records the total amount of resin pumped through the system.

#### i. Woven Roving Fiberglass Dispenser

During the latter part of Phase I, a woven roving fiberglass material was evaluated for use with lower viscosity, unfilled resins. The material was found satisfactory for use in sites not requiring the high temperature resin. The first attempt to use the material in the preparation of a site involved hand carrying the material to the site and unrolling it by hand. The process was time-consuming, as the woven roving

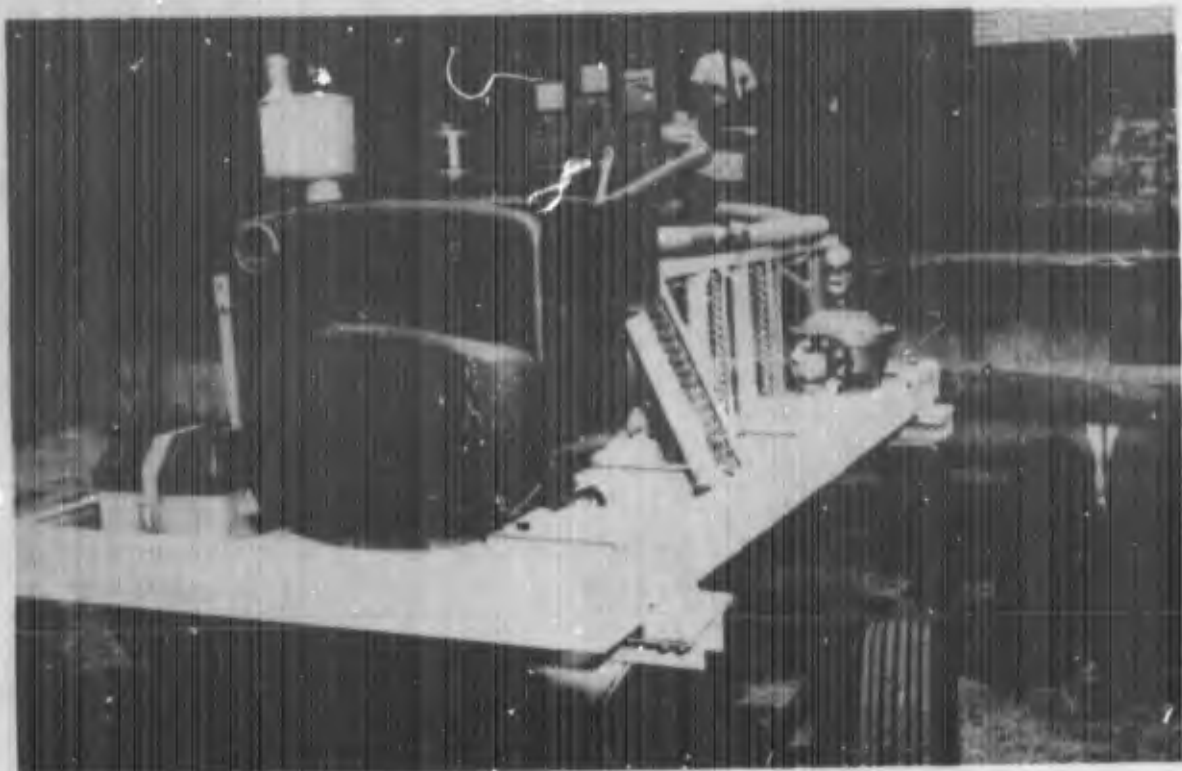
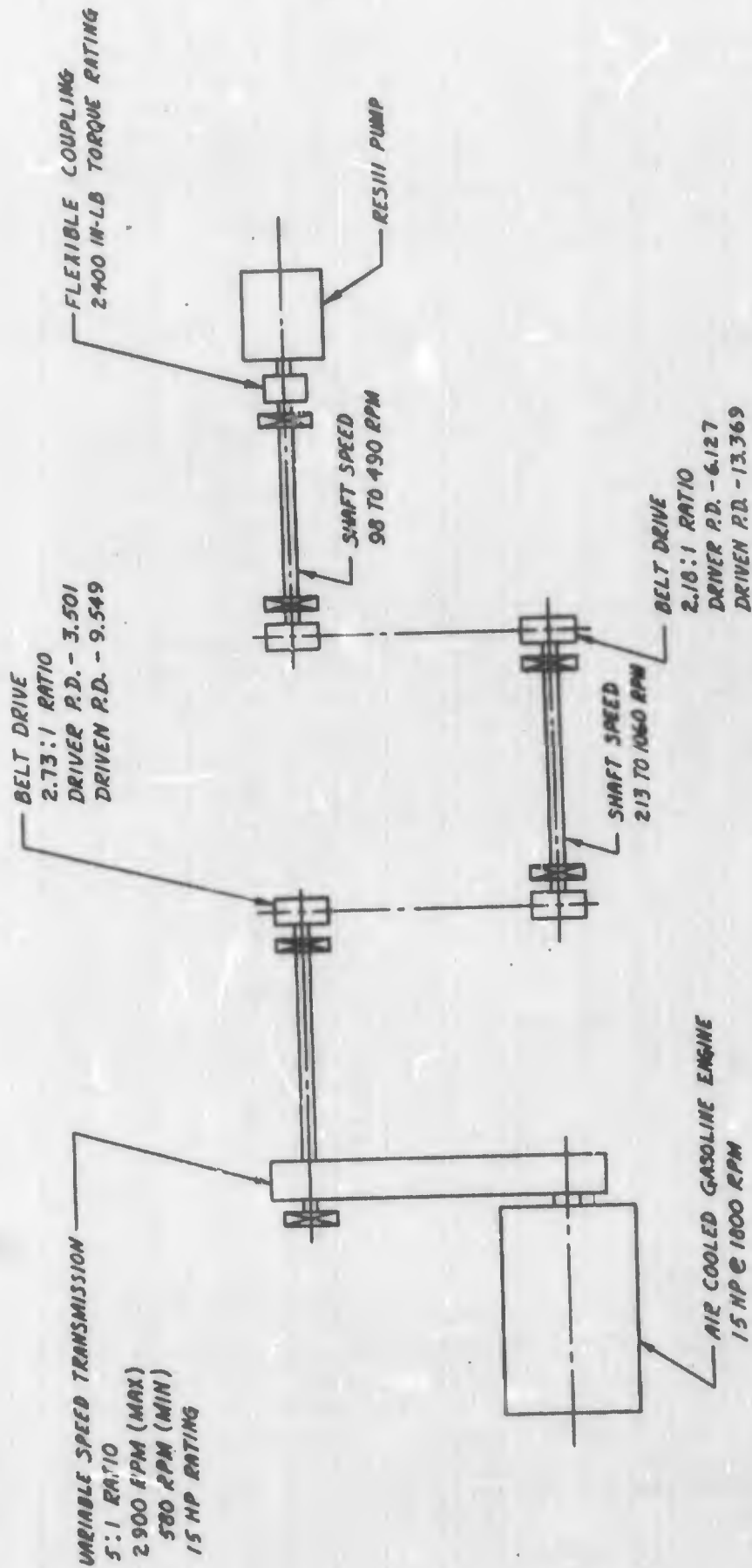


Figure 51. Portable Transfer System Assembly - Side View



Figure 52. Portable Transfer System Assembly



RPM	H.P.	TORQUE (IN-LB)	VISCOSITY (SSU)	GPM
125	3.9	1965	250,000	12
190	5.3	1760	74,000	18
270	5.7	1330	10,000	27

BASED ON VIKING MODEL K-124, 175 PSI

Figure 53. Portable Resin Transfer Pump

is overlapped 50% of the width of the roll. A device was obviously required for transporting to the site and for the actual dispensing of the glass cloth. A dispenser was designed, using 4:00 x 8 industrial pneumatic tires (Figure 54). This permits glass to be transported from a stock pile location to the site. Two tube assemblies were constructed, to be inserted into the ends of the glass rolls with a handle extending from the end of each tube. A slotted arm was provided on each end of the dispenser into which the handles were inserted. A small hook-type keeper (with spring tension), mounted on each of the dispenser arms, holds the handle in the slots. A flange on each tube assembly keeps the glass roll centered between the arms. With the glass in position to be dispensed, the dispenser is rotated about the glass roll and the roll is pulled by the operator, laying the glass cloth on the terrain. The wheels of the dispenser are above the frame during this operation, as shown in Figure 55. Because the cardboard tubes on which the glass cloth is rolled are not strong enough to support the glass, a stiffening tube was provided to support the glass during transport. It is a single tube with both ends swaged to facilitate guiding of the tube ends into the end tube assemblies as they are inserted into the glass roll liners. The single tube is of sufficient length to fully support the roll between both of the end tube assemblies. During the design program, longer glass rolls were also used, requiring an extension for the dispensers which could be reversed to handle either 80-inch or 100-inch rolls. The arms were made removable for use in three different locations. This also required longer supporting tubes between the end tube assemblies. Because of the extreme width of the 100-inch rolls, the operator's handle was extended for better control during transport and dispensing. The extension provides an additional 14 inches outside of the original handle and is supported by a brace from the main frame of the dispenser. This addition was incorporated just prior to shipping the dispensers to Eglin AFB, and Figures 54 and 55 do not reflect the change.

The 100-inch glass ordered for the Eglin Air Force Base Site was mounted on 4-inch. I. D. cardboard tubes. Since the design diameter was for a 3-inch I. D. liner, a large washer type guard was provided for use on the end tube assemblies, insuring that the glass roll would remain centered on the dispenser during dispensing operations.

#### j. Hose Support Boom

One of the operational problems experienced during the European tests was that of managing long hoses lying on the ground from the prime mover to the pole guns. This has become a more serious problem since the post-Europe resin plumbing modifications, which increased the size and lengths of these hoses, as described in paragraph b, page 98. Future concepts could eliminate this problem if the prime mover moved occasionally while applying the site materials from shorter hoses suspended on a boom.

To further evaluate the potential usability of this concept, a boom was designed and fabricated for test. The system consists of a three-part, segmented, 25-foot long truss-frame boom (Figure 56), a 3-foot

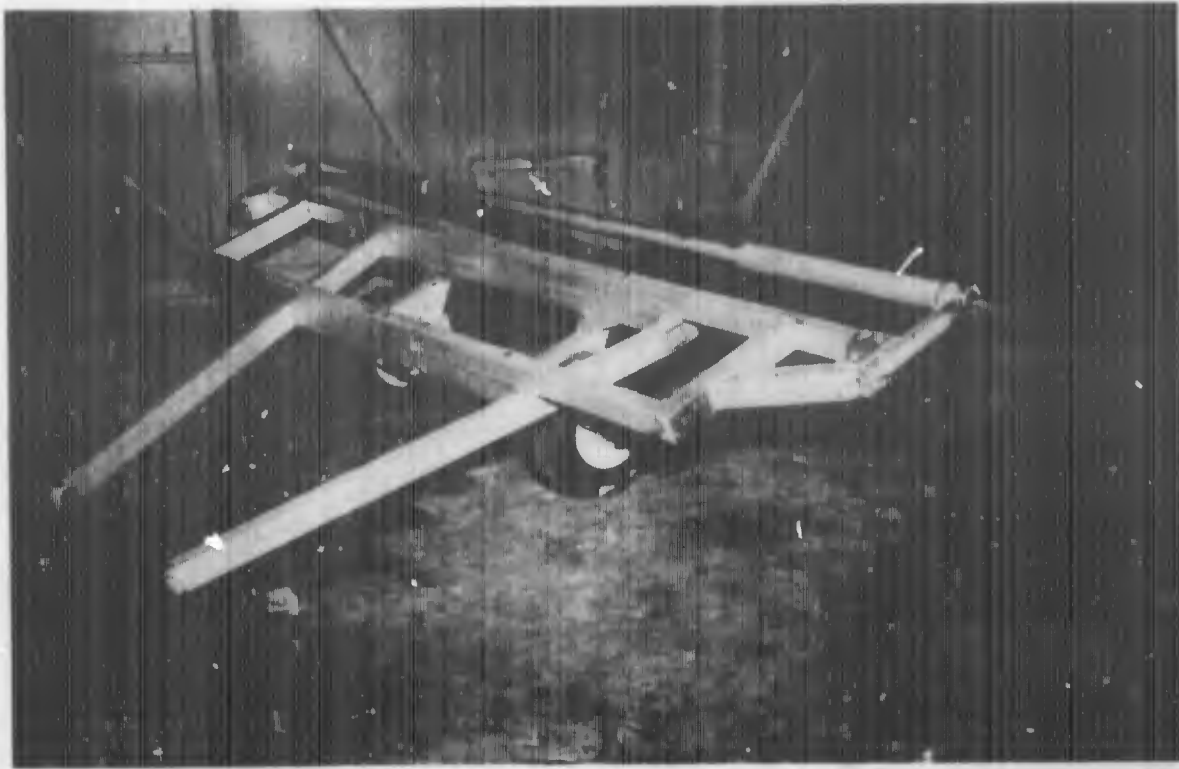


Figure 54. Woven Roving Dispenser in Position for Transport of Fiberglass

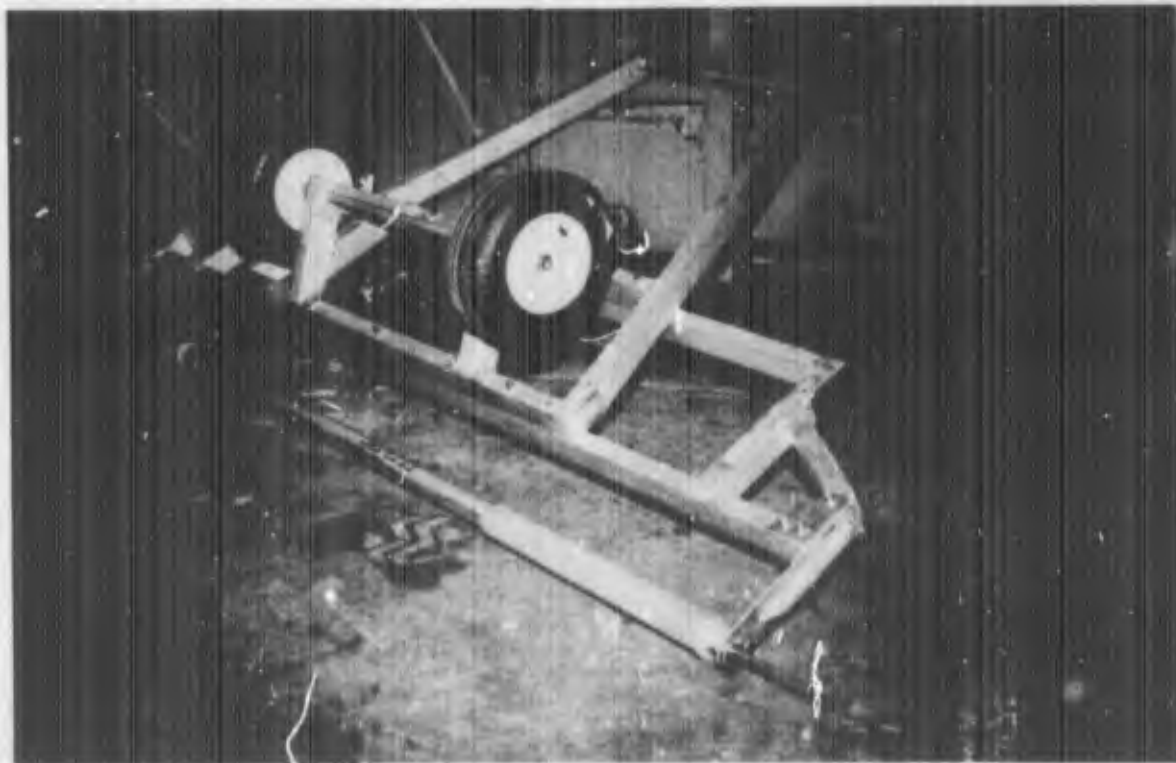


Figure 55. Woven Roving Dispenser in Position for Unrolling Fiberglass

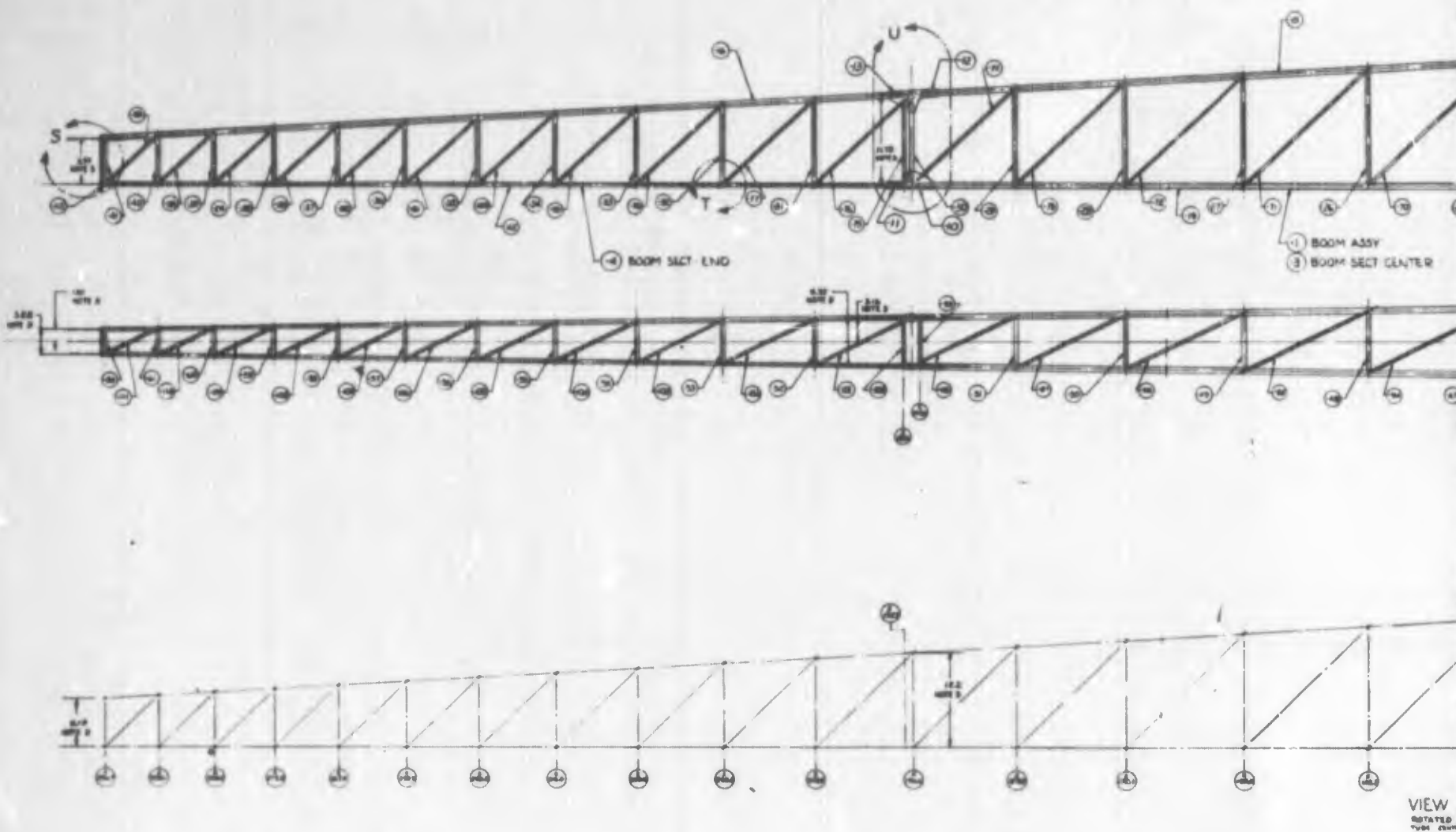
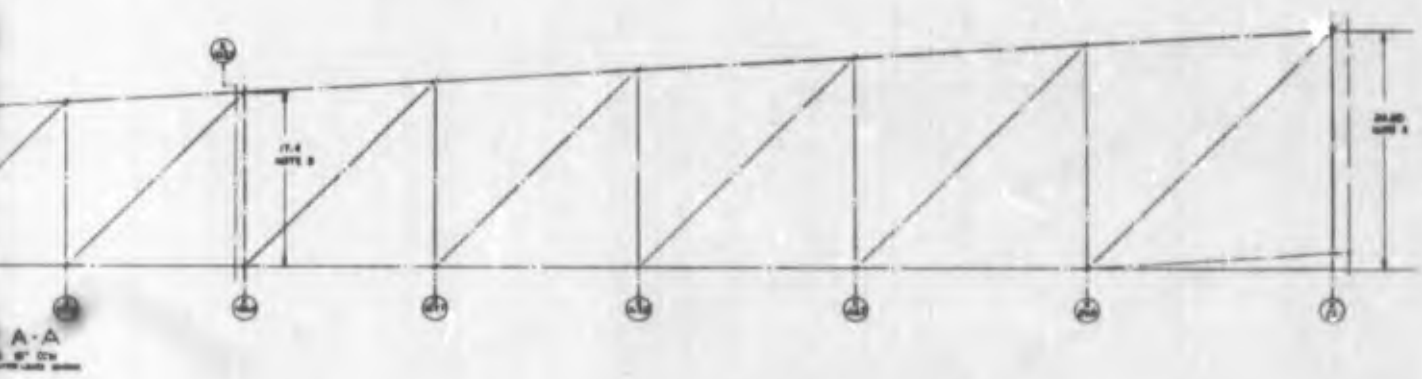
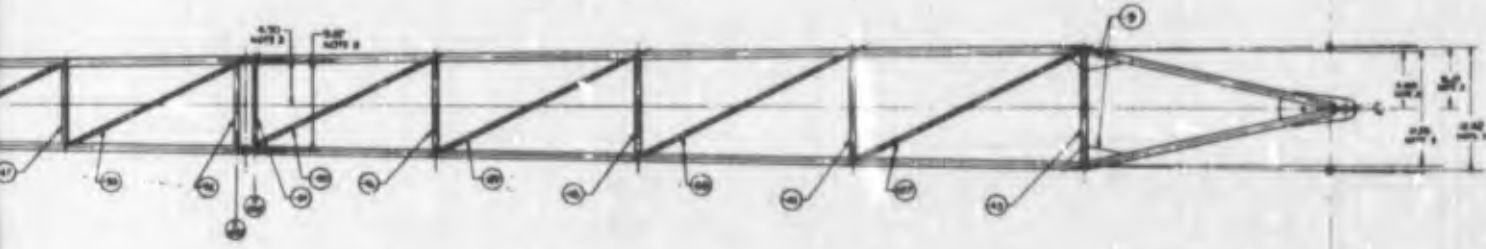
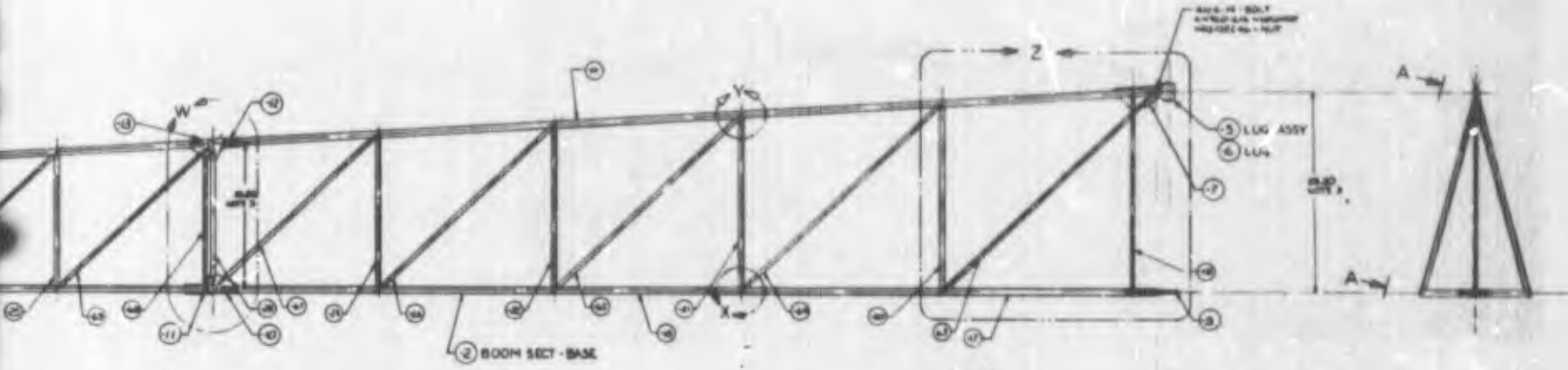


Figure 56. Prime Mover Boom Assembly Spray Hose Support

A

**NOTES:**

1. HOLE IN TUBES TO BE DRILLED AFTER BOOM BLUE WELDMENTS ARE COMPLETE TO ASSURE PROPER ALIGNMENT OF HOLES.
2. BOOM JOINT FIT/MAKE-UP IS TO BE MADE IN LINE WITH DRILLED AT ANGLE TO MAINTAIN BOOM ALIGNMENT.
3. DIMENSIONS GIVEN ARE CONTROL DIMENSIONS TO SET BOOM VERTICAL AND INDICATE TUBE CENTERLINE POSITION. DIMS LOCATE VERTICAL (MEMBERS) AND HORIZONTAL (CHORD MEMBERS) ALL VERTICAL TUBES TO DIMENSIONS SHOWN TO BE ADJUSTED TO MAKE TUBE VERT. W/O.
4. ALL TUBE JOINTS & TUBES AND JOINTS TO BE DRILLED TO O.D. NO UNDESIRABLE HOLE IS TO BE PERMITTED. ALL HOLES TO BE WORKMANSHIP QUALITY FINISH. HOLES TO BE DRILLED PERPENDICULAR TO SURFACE OF TUBES TO BE DRILLED PERPENDICULAR TO CUTTING TO MAINTAIN FULL CONTACT FOR WELDING.
5. TUBES TO BE CUT AS FOLLOWS:
  - A. FOR JOINTS (SEE DRAWING FOR DETAILS)
  - B. FOR CUT (SEE DRAWING FOR DETAILS)
  - C. FOR CUT (SEE DRAWING FOR DETAILS)
6. ALL TUBES REQUIRED TO BE DRILLED FOR SECTION C-CHORD MEMBERS AND WELDED AFTER WELDING AS FOLLOWS:
  - A. FOR 2x4x1/2 (TUBES) - DRILL 1/2" DIA. HOLES WITH 1/4" DIA. DIA. DIA. DIA. DIA. DIA.
  - B. FOR 2x4x1/2 (TUBES) - DRILL 1/2" DIA. HOLES WITH 1/4" DIA. DIA. DIA. DIA. DIA.
7. ALL TUBES TO BE DRILLED TO O.D. TO BE DRILLED TOWARD EACH END. ALL REMAINING TUBES TO BE DRILLED TO O.D. TOWARD EACH END.



B

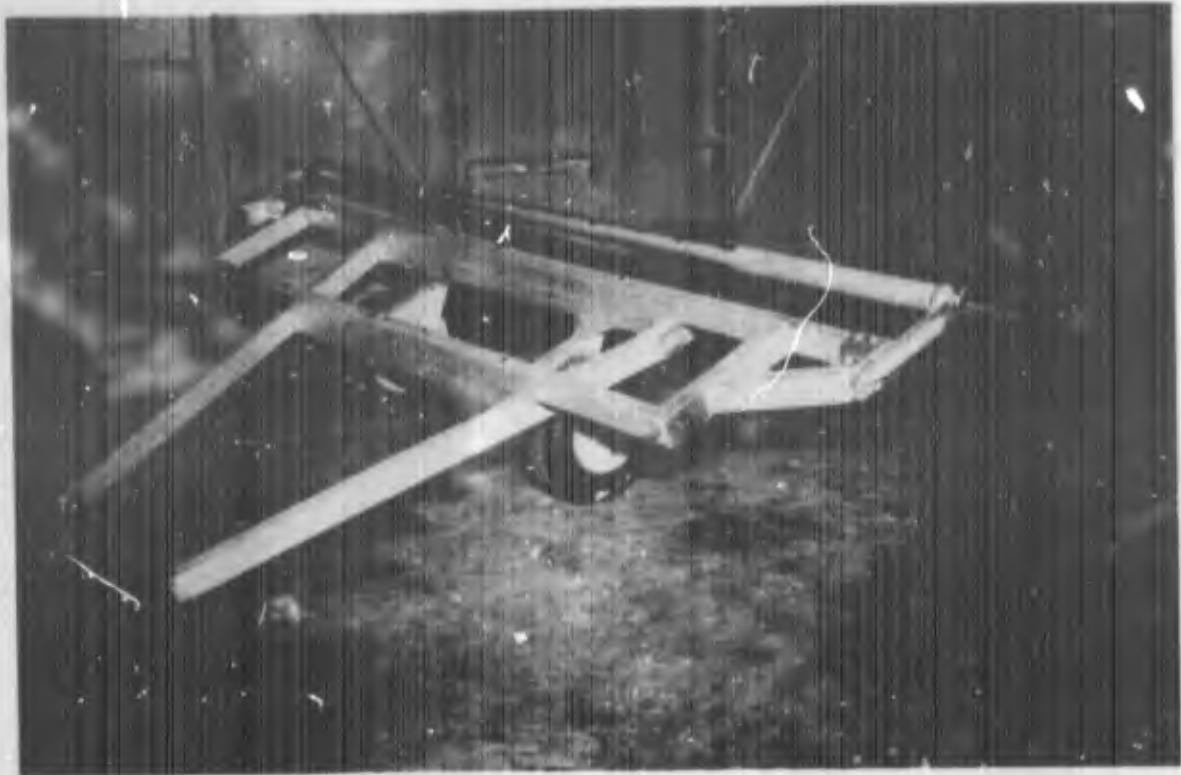


Figure 54. Woven Roving Dispenser in Position for Transport of Fiberglass

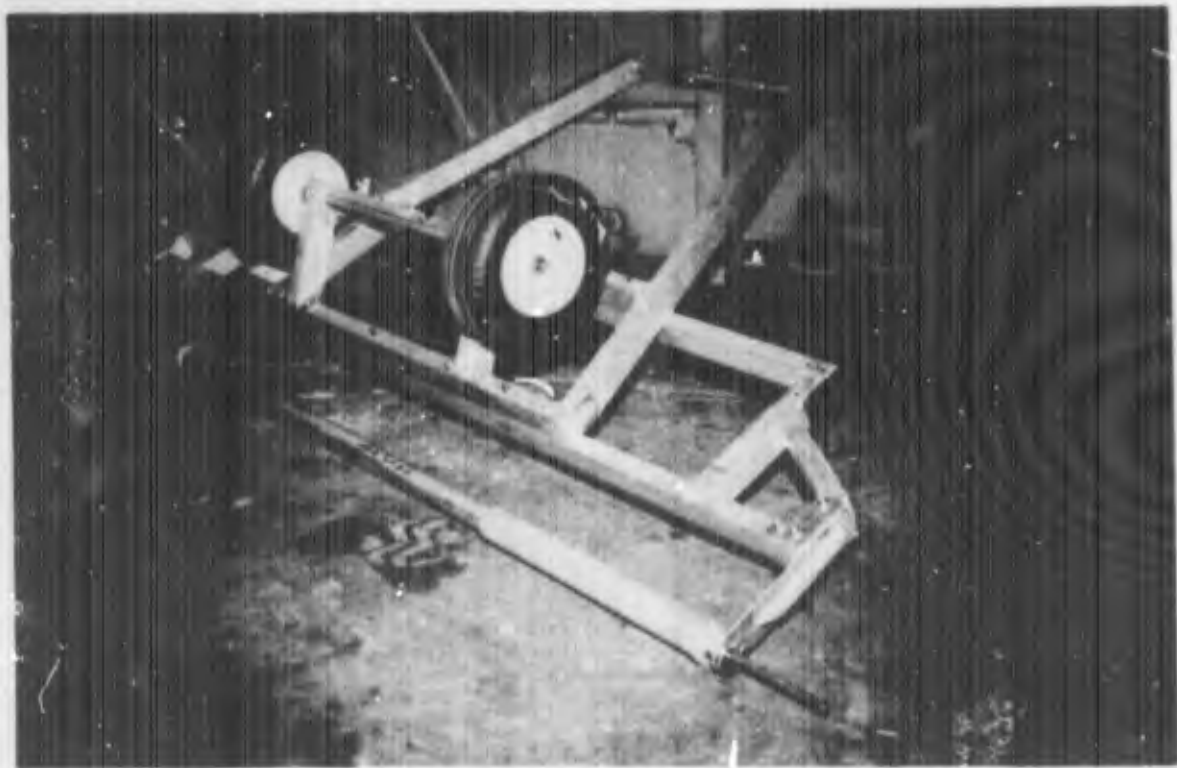


Figure 55. Woven Roving Dispenser in Position for Unrolling Fiberglass

spring loaded balance arm, and a 3-plane-rotation swivel joint. The resin and catalyst hoses (see Figure 57) will be supported by the boom with resin flow going through the balance arm, the 3-plane swivel, and another length of hose to the pole gun.

Preliminary evaluation will be conducted using a test stand, Figure 58. This unit will permit the boom to be mounted at two different heights above the ground, to evaluate the most desirable elevation for the boom when mounted on the prime mover. Secondary tests will be performed with the boom mounted on the prime mover and with actual spraying operations being conducted. (Note: To permit these tests with the boom mounted on the prime mover, the boom was designed as a tubular trusswork frame for minimum weight).

It is planned that preliminary and secondary evaluation tests on the hose support boom will be conducted during Phase II of the Rapid Site program.

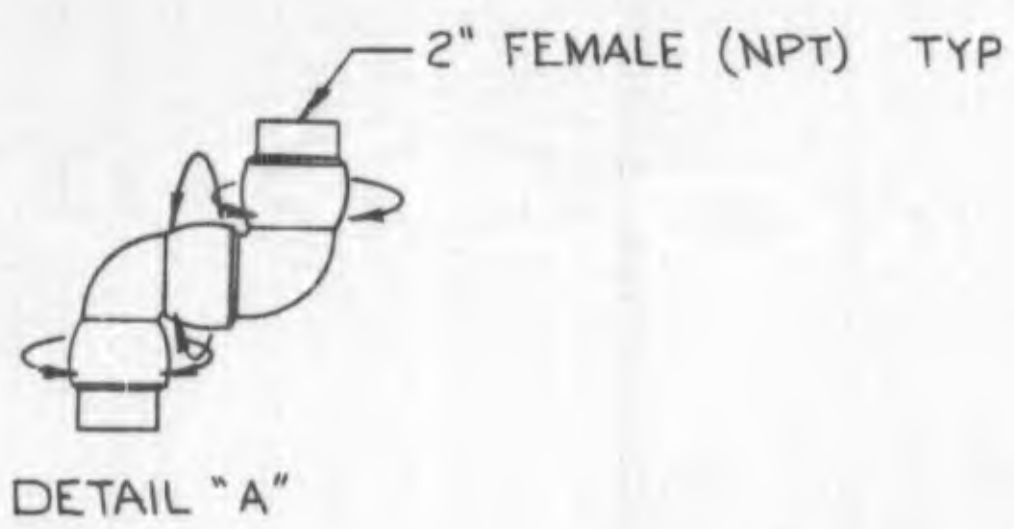
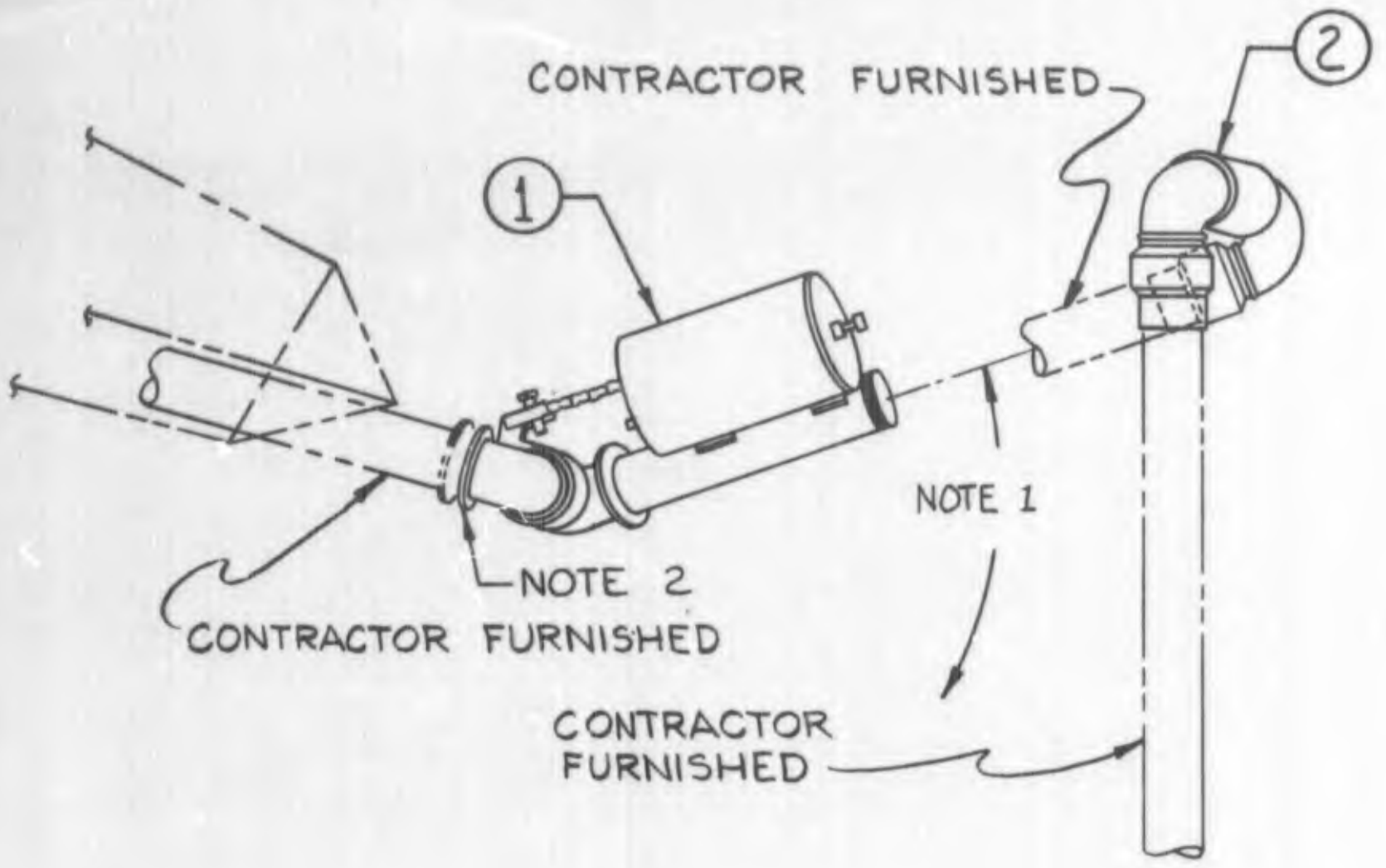
#### k. Miscellaneous Equipment

During all of the Phase I application equipment design program, emphasis was placed on miscellaneous equipment items to the same degree as on the primary equipment items, the prime mover and the tank trailer. Some of the larger items of miscellaneous equipment such as the portable resin transfer pump and the woven roving glass dispenser, have been discussed in previous paragraphs. This paragraph will discuss some of the significant but smaller equipment items without which application operations could not have been conducted.

Figure 59 shows the portable solvent pump, used primarily for transfer of solvent to the solvent pot on the prime mover and for cleanup operations. The pump is a five gpm unit, a positive displacement type manufactured by Viking. It is driven by a one horsepower air motor which operates on 100 psi air from either the prime mover or shop supply. A control valve on the motor air supply provides control of pumping rate. To minimize weight, the unit is mounted on a base of formed aluminum sheet.

Additional items of miscellaneous equipment, as well as the major items, are listed on the chart of Figure 60. Most of these items are conventional in nature and are self-explanatory, but the following items are presented with a description of their use:

The barrel lift and the drum hook were provided to supplement existing material handling facilities at application sites. In spite of the experimental nature of the Rapid Site program, and the probability of finding available military handling equipment at whatever locations were selected for site operations, these items were added to the inventory as a contingency. During the European tests, particularly in England, they were quite useful because of the remoteness of the facility from the military base.



A

ITEM	DESCRIPTION	REQUIREMENTS
<u>1</u>	SPRING BALANCED BASE ARM SECTION	2" NPT FLANGED SWIVEL ELBOW.- SPRINGS MUST HANDLE A MOMENT LOADING OF 6,602 IN.-LB. MATL - STEEL
<u>2</u>	SWIVEL JOINT ELBOW	3 PLANES OF ROTATION - SEE DETAIL "A". SIZE- 2"; MATL- STEEL

NOTE

1. FULL PRE-SET STOP ADJUSTMENT AT ANY ANGLE IN VERTICAL PLANE.
2. MAXIMUM LOADS APPLIED AT THIS JOINT BY CONTRACTOR ARE: 6,602 IN.-LBS MOMENT AND 184.4 LBS SHEAR.

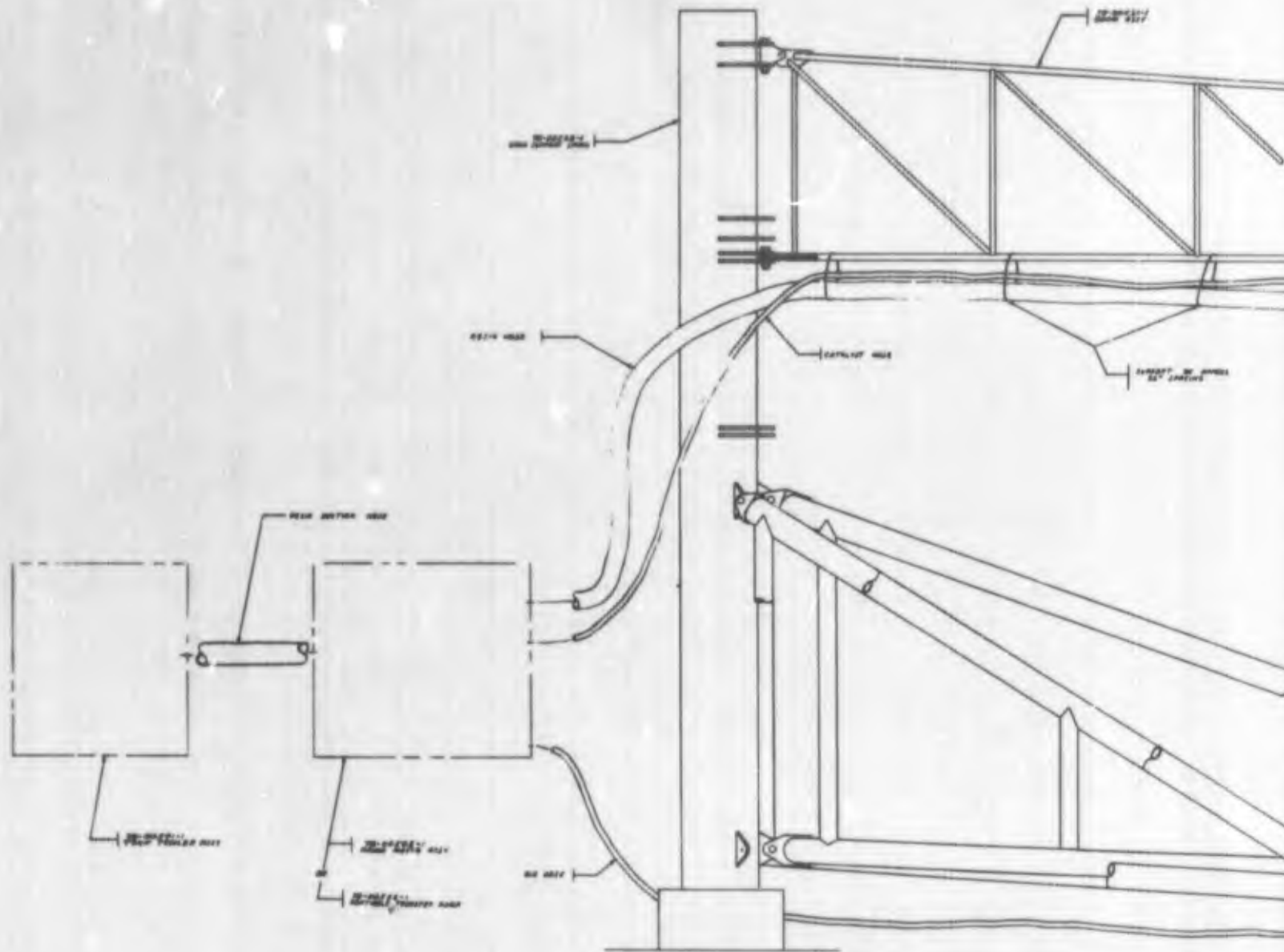
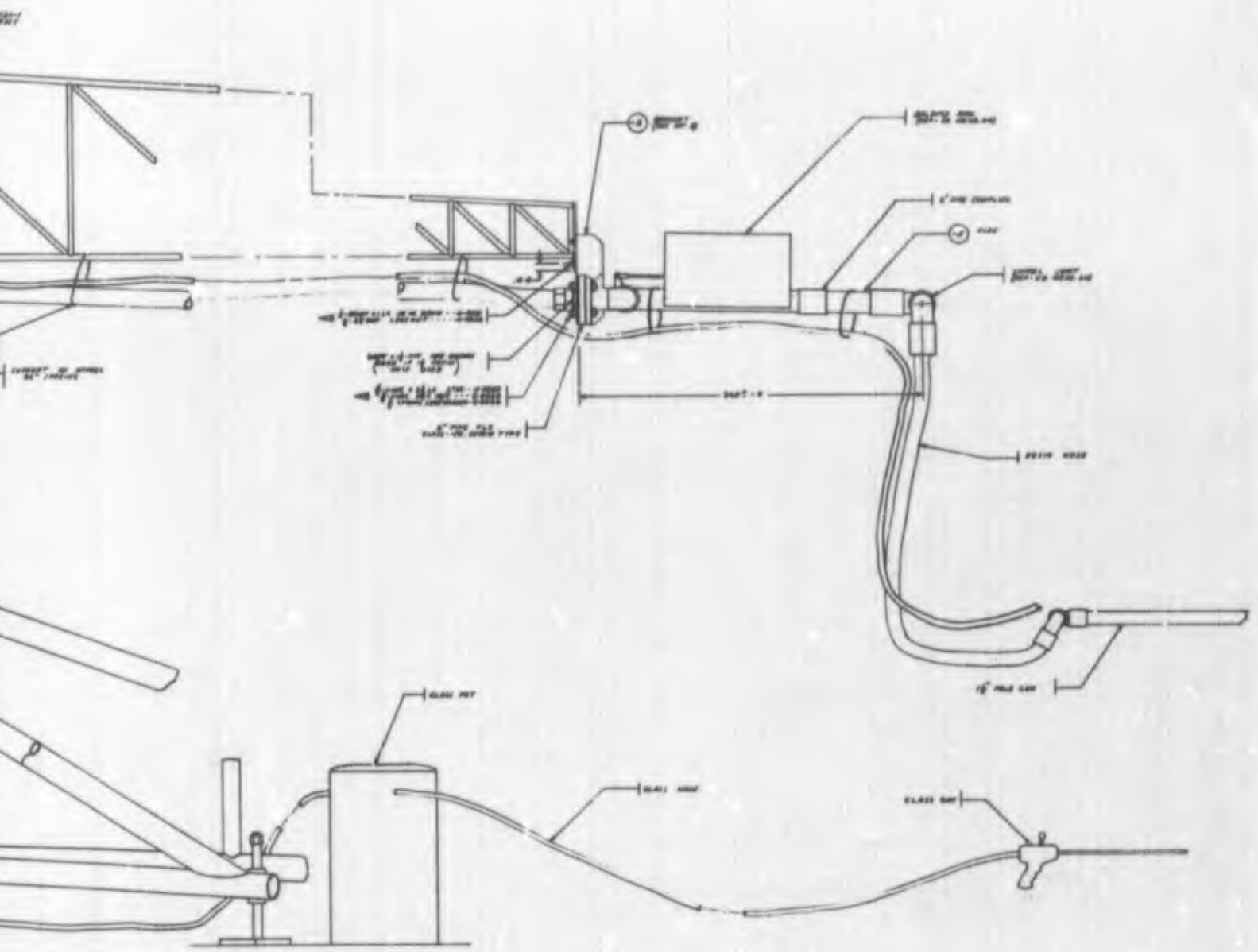


Figure 58. Test Set-Up Hose Support Boom

A



B



Figure 59. Portable Solvent Pump

QTY REQD	NOMENCLATURE	VENDOR PART NO.	VENDOR	REQD
4	Tank Assy	78-00500-1	LTV	
1	Prime Mover	78-00505-1	LTV	
2	Drum Opener		Briggs-Weaver, Dallas	EOL
2	24" Pipe Wrench		Briggs-Weaver, Dallas	N
2	10" Pipe Wrench		Briggs-Weaver, Dallas	N
1	First Aid Kit	Johnson & Johnson Industrial First Aid Kit	Dallas First Aid Supply Co.	EOL
1	Gas Cap, Locking	Rex No. A550	Dubs Auto Parts, Grand Prairie	EOL
5 Bags	Marble Dust 50 lb	Southwest Sales Co. Inc. Dallas, Texas		EOL
2	Drinking Water Can	Gotkool No. PR5	Briggs-Weaver, Dallas	EOL
3	Barrel Faucet	Sherman No. 105	Briggs-Weaver, Dallas	EOL
3	Oil Gate Valve	Perfection No. 75	Briggs-Weaver, Dallas	EOL
4	Safety Cans-5 Gal	Justrite No. 10800	Briggs-Weaver, Dallas	EOL
Noted	Instrumentation Equipment	78-00525	LTV	
1	Solvent Portable Pump Assy	78-00519	LTV	
1	Instrumentation Trailer	F28K6150NF & 28K6183N	Sears, Roebuck & Co.	EOL
1	Portable Spotlight	28K5534	Sears, Roebuck & Co.	EOL
2	Drop Cloths (Roll Polyethylene) Caps with "Rapid Site"			EOL
	Personnel Coveralls			EOL
	Plastic Gloves			
	Plastic Overshoes	Furnished by		
6	Face Shields & (12) Safety Glasses (Sun)	LTV Safety Dept		
	Brake Actuation Kit	1100-3	Hadco Engineering Co., Los Angeles, Calif.	EOL
1	Intercom Set			
1 Ea.	Solvent Pump Hose	78-00509-14 & -15		EOL
1	Hose Band Tool	J001	Band-It Co.; Denver, Colo.	EOL
2	Fire Extinguisher	20-R(Exting.-20#) 20-RB(MTG BKT)	Briggs-Weaver	EOL
2	Tank Paddles		Tamco Plastic Supplies, Lima, Ohio	EOL
1	Line Marker	56-169	Cullum & Boren, Dallas	
1	Grease Gun	Alemite 1056-SE	Briggs-Weaver	EOL
2	Tire Gage	Diamond-U1040	Service Station Supply & Equip Co., Dallas	EOL
1	Parts Catalog	Chrysler Parts Cat. Dodge Truck, S-Series, Ser. No. 1,230,000	(Same as below)	EOL
1	Service Manual	Dodge Truck, Models 100-700 Conv. Fwd. Control 4 x 4	Dodge Truck Operations, Dodge Div., Chrysler Motors Corp., Detroit, Mich.	EOL
1	Adapter	7239-1037 Part F	Gates Rubber Co.; Dallas, Texas	EOL
1	Shank Coupler	7239-1023 Part C	Gates Rubber Co.	EOL
1	Drum Hook	No. 41	Morse Mfg. Co.; Syracuse, N.Y.	EOL
1	Barrel Lift	Morse Mod. 85	Morse Mfg. Co.; Syracuse, N.Y.	EOL

Figure 60. Accumulation Chart - Rapid Site Phase I Application Equipment

VENDOR	REQ. NO.	DATE	ANTIC. DATE	ACTUAL RECEIPT DATE	MISCELLANEOUS
Reaver, Dallas	E010034.15	8/10/65	8/27-65		2 Spare Sets Cutting Blades
Reaver, Dallas	Noted	8-6-65			Petty Cast No. 5485
Reaver, Dallas	Noted	8-6-65			Petty Cash No. 5485
First Aid Supply Co.	E010034.12				
Parts, Grand Prairie	E010034.10	8-3-65			
	E010034.10	8-3-65			
Reaver, Dallas	E010034.10	8-3-65			
Reaver, Dallas	E010034.10	8-3-65			
Reaver, Dallas	E010034.10	8-3-65			
Reaver, Dallas	E010034.10	8-3-65			
		7-23-65			
		7/19/65	7-23-65		
Deebuck & Co.	E010034.5	7-14-65	7-22-65		
Deebuck & Co.	E010034.5	7-14-65	7-22-65		
	E010034.14	8-6-65	8-16-65		Insignias Ordered by E010034.10
	E010034.14	8-6-65	8-16-65		Insignias Ordered by E010034.10
Engineering Co., Fresno, Calif.	E010033.26	7-12-65	7-23-65		For the Land Rover
	E010033.20	7-8-65	7-16-65		
Co.; Denver, Colo.	E010034.3	7-8-65	7-15-65		
Reaver	E010033.27	7-12-65	7-15-65	7/16/65	
Plastic Supplies, Dallas	E010033.14	7-1-65	7-9-65	7-12-65	
Boren, Dallas Reaver	E010034.4			7/16/65	With 6652-A Hose & 2 Extra 6304-B Couplings
Station Supply & Equip Dallas	E010034.4	7-20-65		7/16/65	
(below)	E010033.11	6-29-65	7-9-65		
Truck Operations, Dodge Div., Motors Corp., Detroit, Mich.	E010033.11	6-29-65	7-9-65		
Huber Co.; Dallas, Texas	E010033.8	6-28-65	7-6-65	7-8-65	Test-System Campatibility Only
Huber Co.	E010033.8	6-28-65	7-6-65	7-8-65	Test-System Campatibility Only
G. Co.; Syracuse, N.Y.	E010034.1	7-2-65	7-23-65		
G. Co.; Syracuse, N.Y.	E010034.1	7-2-65	7-23-65		

Equipment

*B*

A resin hose wrench, Figure 61, was designed for use on the resin hose suction lines, because no suitable commercial wrench of reasonable cost could be found.

The earth anchor wrench, fabricated during the final week of the program for use during Phase II operations at Eglin, is used to drive auger-type earth anchors into the soil at the bottom of the edge preparation ditch. Details of the earth anchor, its load carrying capabilities in various soils, and the use of the wrench or equipment which might replace it, will be described in reports on the Phase II program.

#### 1. Equipment Checkout and Operation - Post-Europe

Following the tests, design, and modifications described in the foregoing paragraphs, the post-European application equipment was checked for proper operation. The checks consisted of leakage tests and operational tests of the various subsystems, individually and collectively. Inasmuch as operating personnel for Phase II application operations included personnel who had made the modifications, very little training was required. To verify that the entire system was capable of applying materials satisfactorily, resin and glass spraying operations were conducted at ITV, as shown in Figure 62.

To document the changes in operational procedures required by the post-Europe modifications, the Equipment Operations Instructions (Reference 3) were rewritten, Reference (4). This new set of operations instructions includes the photographs of this report, with components identified by letters indicated on the system schematic, shown in Figure 35. This schematic is also included in Reference (4).

Figure 63 shows the major items, the prime mover and the four resin tank trailers, following completion of all of the post-Europe modifications, being tested for satisfactory operation of the tank trailer suspension and brake systems. Figure 64 is a general arrangement drawing of the prime mover, which reflects the changes made to the various subsystems.

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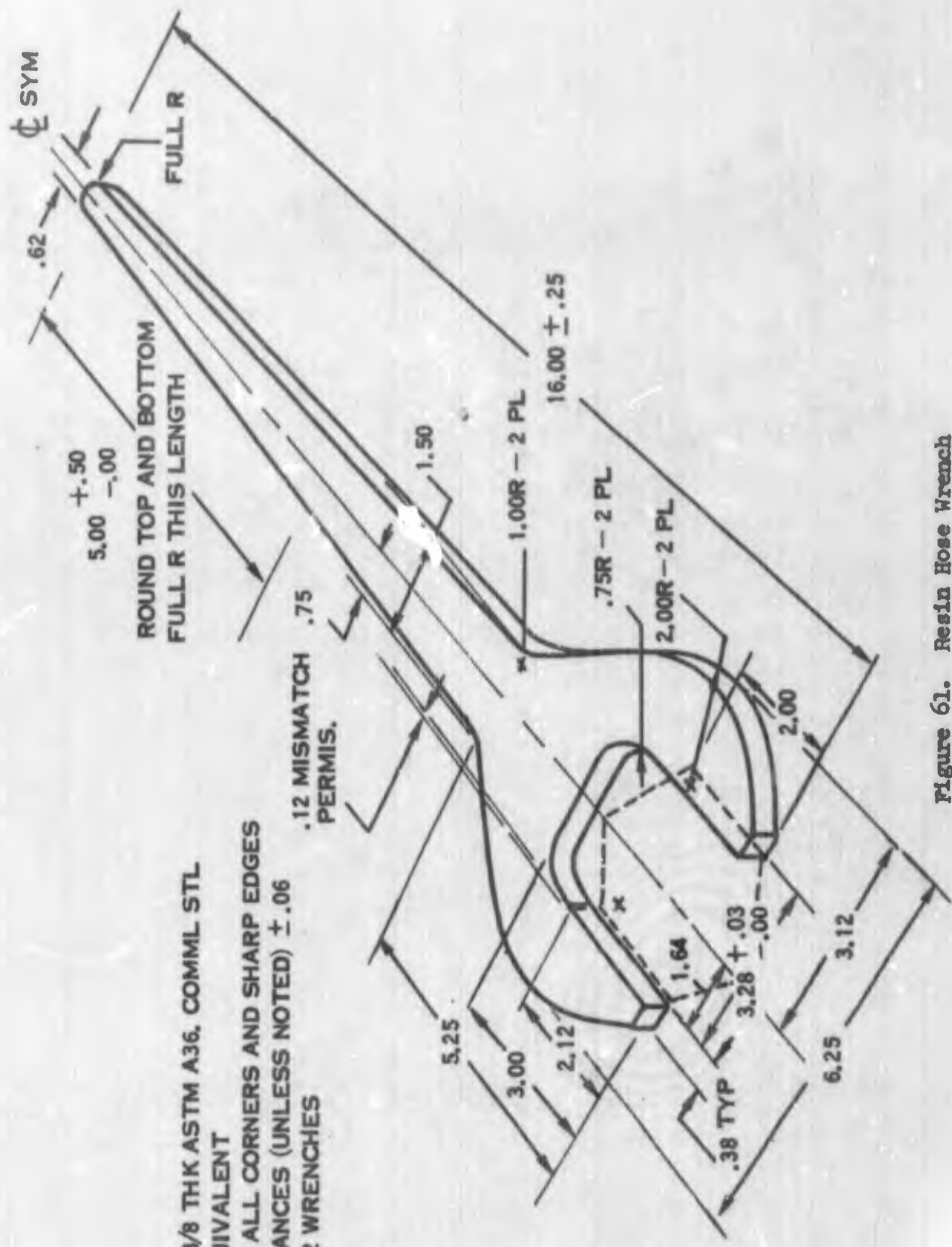


Figure 61. Resin Hose Wrench



Figure 62. Equipment Testing - Post Europe Modifications

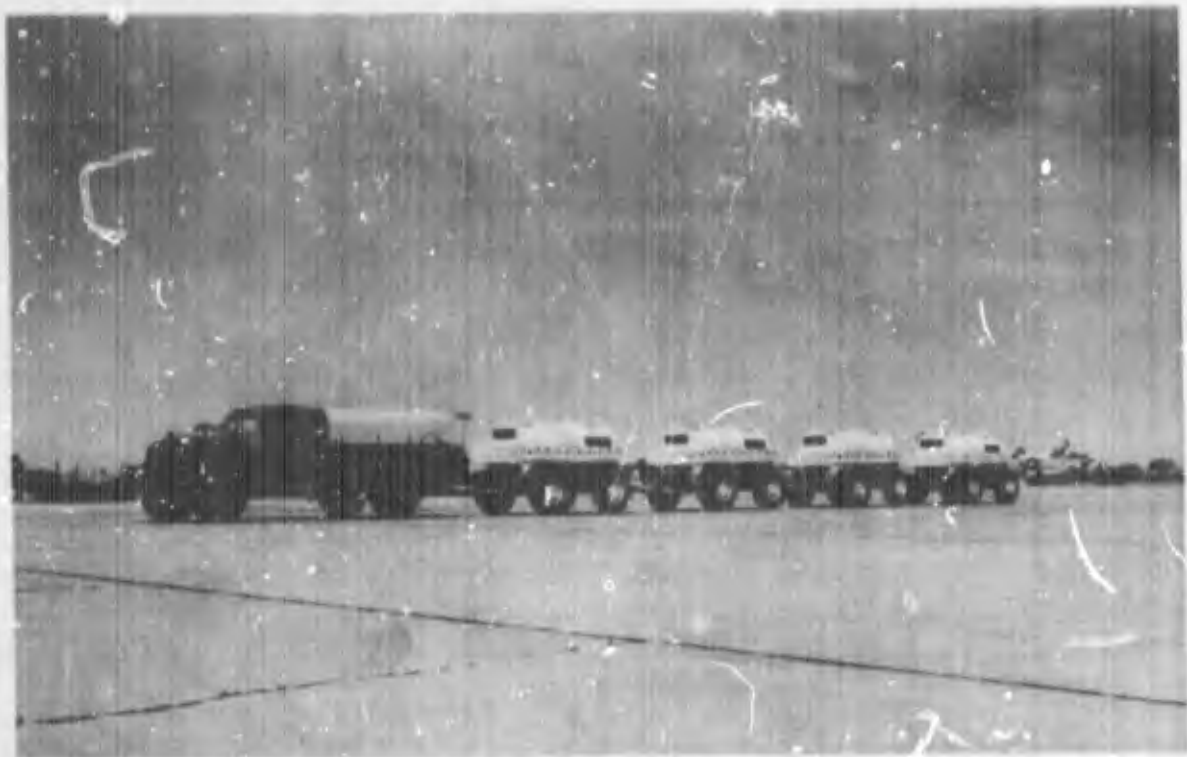
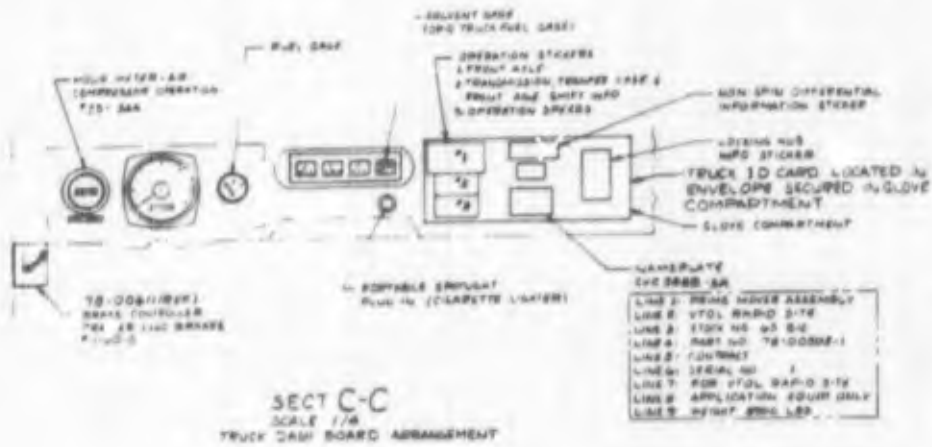


Figure 63. Prime Mover and Tank Trailers - Post-Europe



DWG. NO.	TITLE	ISSUED	REVISED
WM-300	DOODGE POWER WAGON TRUCK		
78-00502	BRAKE ASSY RESIN PUMP	-1	-
78-00501	WIRING DIAG BRAKE CONTROL, BRAKE LIGHTS	-1	-1
78-00510	PLUMBING INSTL	-1	-12-B
78-00508	AIR RECEIVER INSTL	-1	-1
78-00502	HOSE BACK	-1	-2-B
78-00501	TIE DOWN GLASS POTS	-1	-1
78-00500	FUEL TANK ASSY	-1	-1
78-00546	CAB EQUIPMENT MOUNT	-1	-1
78-00540	DRIVE WITH PUMP RAMP	-1	-1
78-00527	P.T.O. SHIFTS MECHANISM	-1	-1
78-00528	SOIL DISC	-12-B	-12-B
78-00525	TRUCK BED COVER ASSY	-1	-1
78-00522	RESIN PLUMBING INSTL	-1	-2
78-00521	SOLVENT CATALYST PUT INSTL	-1	-1
78-00520	OPERATORS SEAT INSTL	-1	-1
78-00518	BULLY ASSY TOLER	-12-B	-1
78-00517	CANCELLED	-1	-1
78-00516	PANEL ASSY OPERATORS CONTROL	-1	-81-B
78-00513	PLATFORM ASSY WEAR FENDER	-1	-1
78-00512	CANCELLED	-1	-1
78-00511	FRAME ASSY APPLICATION EQUIP SUPPORT	-12-B	-1
78-00510	CANCELLED	-1	-1
78-00509	S/S SCHEMATIC VENDOR COMPONENTS	-1	-1
78-00508	SYSTEM NAME	ISSUED	ISSUED
78-00507	POWER TRANSFER SCHEMATIC	-1	-1
78-00506	POWER TRANSFER INSTALLATION	-12-B	-1
78-00505	P.T.O. INSTALLATION	-1	-1
78-00502	MARKING DIAGRAM	-1	-1
DWG. NO.	TITLE	-1	-2

**EQUIPMENT APPLICATION TABLE**  
PRIME MOVER

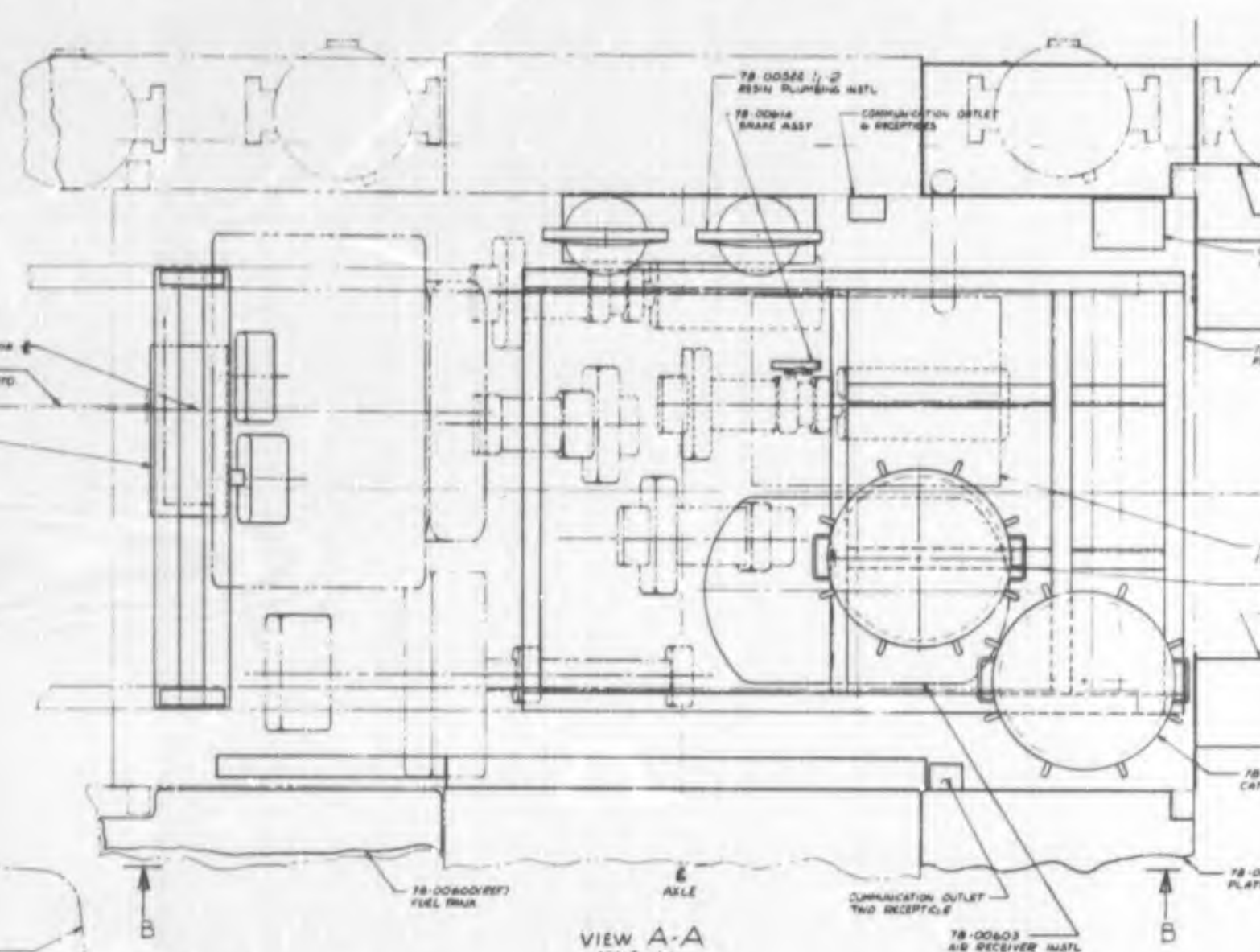
TRUCK CAB OUTLINE REF)

78-00512-1  
FRAME ASSY  
APPL EQUIP SUPPORT

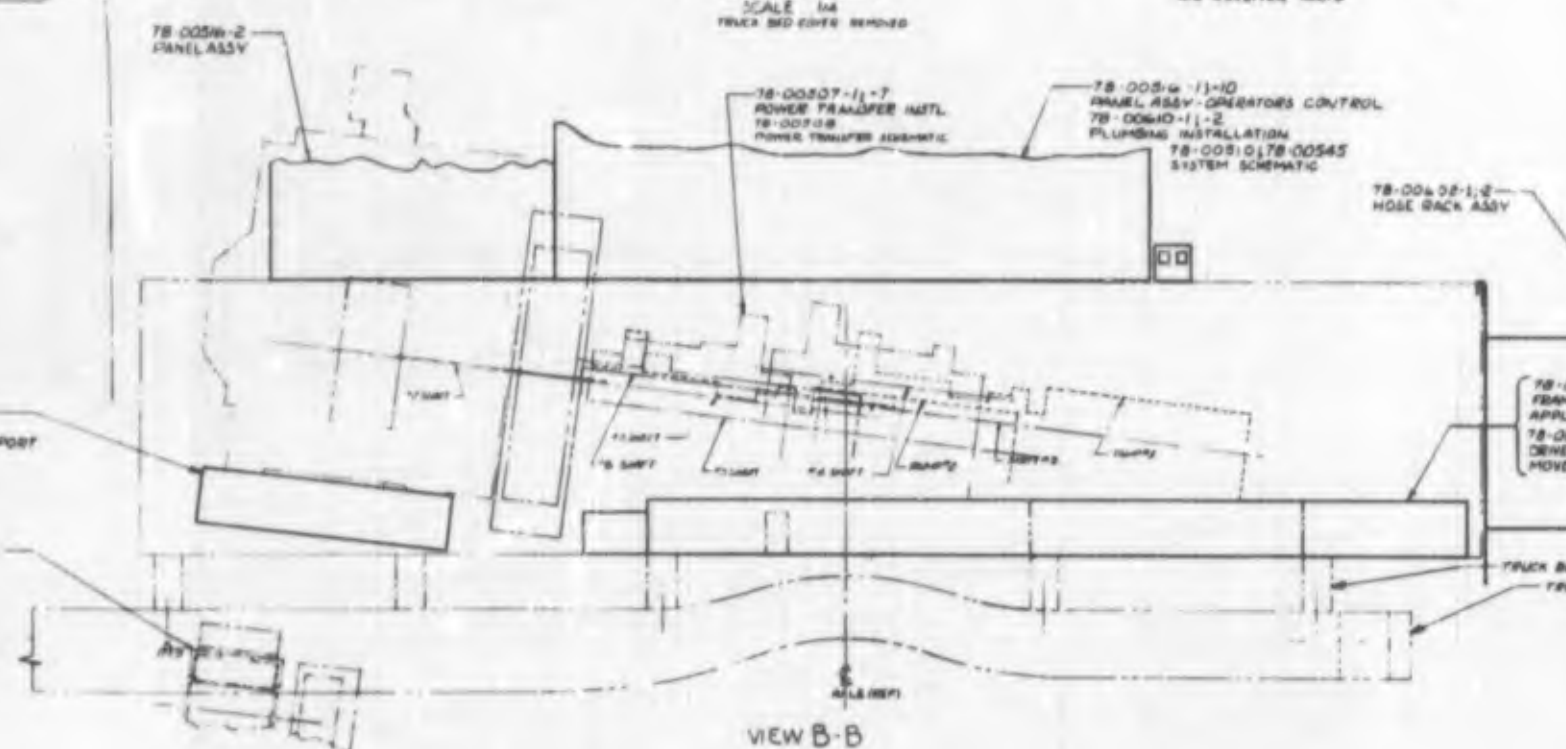
78-00506 (REF)  
P.T.O. INSTL

A

LOCATED IN  
D A.G.O.V.E  
CONVEYOR  
78-00527  
EMF MECH RTD

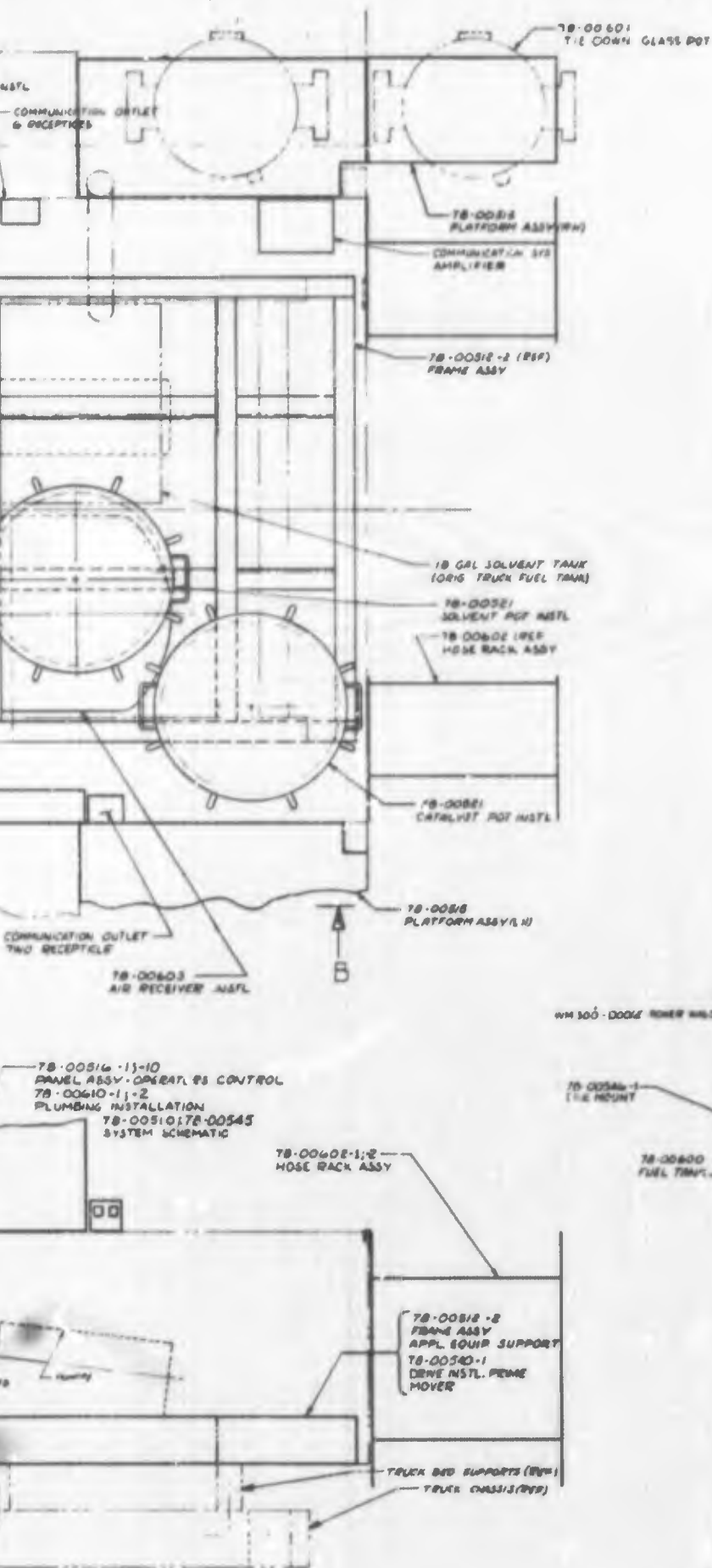


VIEW A-A  
SCALE 1/4"  
TRUCK BED EDGE REMOVED



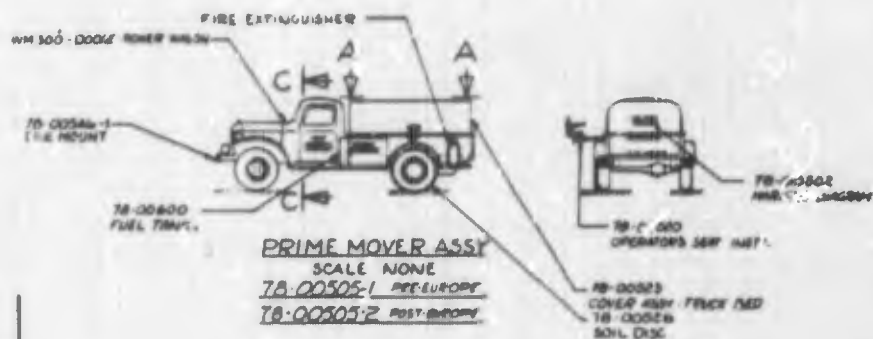
VIEW B-B

B



**NOTE :**

1. PRIME MOVER ENVELOPE
  - A. SHIPPING (ON WHEELS) - 210 LG x 80W x 78 HIGH ON SKID - 210 LG x 80W x 78 HIGH
  - B. OPERATIONAL: 227 LG x 102 W x 79 HIGH
2. ALL EQUIPMENT INSTALLED ON PRIME MOVER IS COMMERCIAL EQUIPMENT AND ALL MAINTENANCE AND SERVICE WILL BE IN ACCORDANCE WITH VENDOR DOCUMENTATION
3. OPERATION OF APPLICATION SYSTEM AS INSTALLED ON PRIME MOVER TO BE IN ACCORDANCE WITH "EQUIPMENT OPERATION INSTRUCTIONS - RAPID SITE" MANUAL AS PREPARED BY ENGINEERING.
4. FRAMEWORK, WITH SAFETY SEATING USED TO COVER THE TRANSFER SYSTEM AND ALSO UTILIZED AS STORAGE PLATFORM FOR GLASS POTS DURING TRANSIT PERIODS IS NOT SHOWN
5. PRIME MOVER SHIPPING SKID WT 1380 LBS
6. PRIME MOVER WEIGHT DATA:
  - A. AS RECEIVED PRIOR TO MODIFICATION - 5230 LB.
  - B. SHIPPING CONFIGURATION - 9290 LB (WITH WHEELS AND WITHOUT HOSES, HOSE RACKS, FIBER GLASS POTS AND COMMUNICATIONS SET)
  - C. EST. SHIPPING WT - 8900 LB
7. SHIPPING CONFIGURATION: PRIME MOVER WITH APPLICATION EQUIP INSTALLED, TRUCK BED COVER, FIBER GLASS POTS, HOSES (DRAINED), HOSE RACKS, COMMUNICATIONS SET, OPERATORS SEAT, ALL STOWED AND SECURED TO SHIPPING SKID. PRIME MOVER WHEELS TO BE REMOVED FOR SHIPMENT, AND ALL HOSES, FLUID POTS & TANKS DRAINED
8. APPLICATION TABLE INDICATES ASSYS AS USED ON PRE- (POST- EUROPE) PRIME MOVER CONFIGURATIONS.



01234567890  
SCALE 1/4"=1'

ISSUE RELEASE #2  
3/16/66

Figure 64. General Arrangement - Prime Mover

C

## 5. ADVANCED SYSTEMS CONCEPTS STUDIES

### a. Introduction

Advanced application equipment concept studies were initiated early in the Phase I program, but were not emphasized to a high degree until completion of the design of the first order application equipment (the pre-European equipment of Section III of this report). While the European tests were being conducted, several concepts for improved application systems were generated and evaluated. In general, these concepts were based on the recognition of the need for operational systems which would require fewer operating personnel and be capable of preparing sites more rapidly than the first order equipment just designed. It was also recognized that the use of handheld spray nozzles for either resin or glass application should be eliminated, if possible, for several reasons. First, such operations require considerable experience and skill on the part of the operator. Second, handheld systems were limited to flow rates of approximately 5 to 7 gallons per minute per operator. Third, use of such systems tended to produce variations in thickness which, in turn, caused weak spots or wasted material.

The foregoing, then, was the basis of the requirements for advanced concept studies. For some of the systems considered during the study effort, assumptions were made as to the desired spray rate, the shape of the pad to be applied, the size of the pad, and other factors which would affect the type of system and the application technique to be used. None of the studies was highly detailed, and most of the analysis conducted on the concepts was qualitative in nature. However, these studies did result in a greater appreciation of the problems involved in applying reinforced fiberglass to large areas of terrain, and the effects of the problems on the equipment requirements.

In the paragraphs to follow, each of the concepts generated during the study period will be described and pictured. For each concept, a discussion will be included of the following points:

- (1) Objectives
- (2) Ground Rules and Assumptions
- (3) Concept Description
- (4) Operational Advantages and Disadvantages
- (5) Problem Areas and Items Requiring Development
- (6) Conclusions

### b. Concept Number 1

The objective of this concept was to provide a system which would be utilized only for application of small diameter round pads (70 feet or less). The concept required a small number of personnel for setting up operations, with minimum personnel required during actual operation. It was assumed that the terrain would be level and comparatively smooth, requiring no touchup to a uniformly applied resin coating. Spray rate was not specified.

Figure 65 shows this concept in operation. The center pivot mounted overhead spray bar is powered by a two-wheel driving mechanism at the outer end. Driving velocity would be set by the operator as a function of the spray rate and the desired pad thickness. The spray bar dispenses both resin and continuous roving fiberglass, which are furnished from the dispensing unit at the periphery of the site through suspended line. Initial set-up is accomplished with a multiman crew, with the spray bar being assembled from several short pieces. The number of pieces used would vary with the diameter of the site.

Advantages of the system include a high degree of mechanization and low number of personnel required for spray operations, uniformity of application, and adaptability to varying diameters of pads. Disadvantages include lack of adaptability to pad shapes other than round ones, high set-up time, need to patch or provide a pad surface at the center after completion of the rest of the pad, probable susceptibility to stoppages in the resin or glass systems with resulting unsprayed areas, and the long lines associated with the geometry of the system. This latter item would increase the line sizes needed for given pressure drops as compared to systems which have lines extended only as far as the radius of the site.

Because of its many disadvantages, this system is concluded to be relatively impractical.

#### c. Concept No. 2

The objective for this concept was to provide a system similar to concept number one, but to eliminate the use of the driving mechanism at the end of the spray bar. This was replaced with a driving system at the center of the site.

The concept is shown in operation in Figure 66. Note that the spray bar is a shorter unit than that of concept number one, and travels along the self-supporting beam.

Advantages for this concept are essentially the same as those for concept number one. Its disadvantages include those for concept number one plus the following: increased weight because of the cantilever construction, more cumbersome to handle with probable higher set-up time, and a more complex plumbing system required because of the traveling spray bar.

This concept, like concept number one, is concluded to be relatively impractical.

#### d. Concept Number 3

This concept was generated as an alternate to numbers one and two, utilizing the same basic objectives. As shown in Figure 67, the concept is basically a self-propelled dispensing system controlled or programmed to follow a helical path about the center of a round pad. The storage tanks aboard the vehicle would require refilling at intervals.

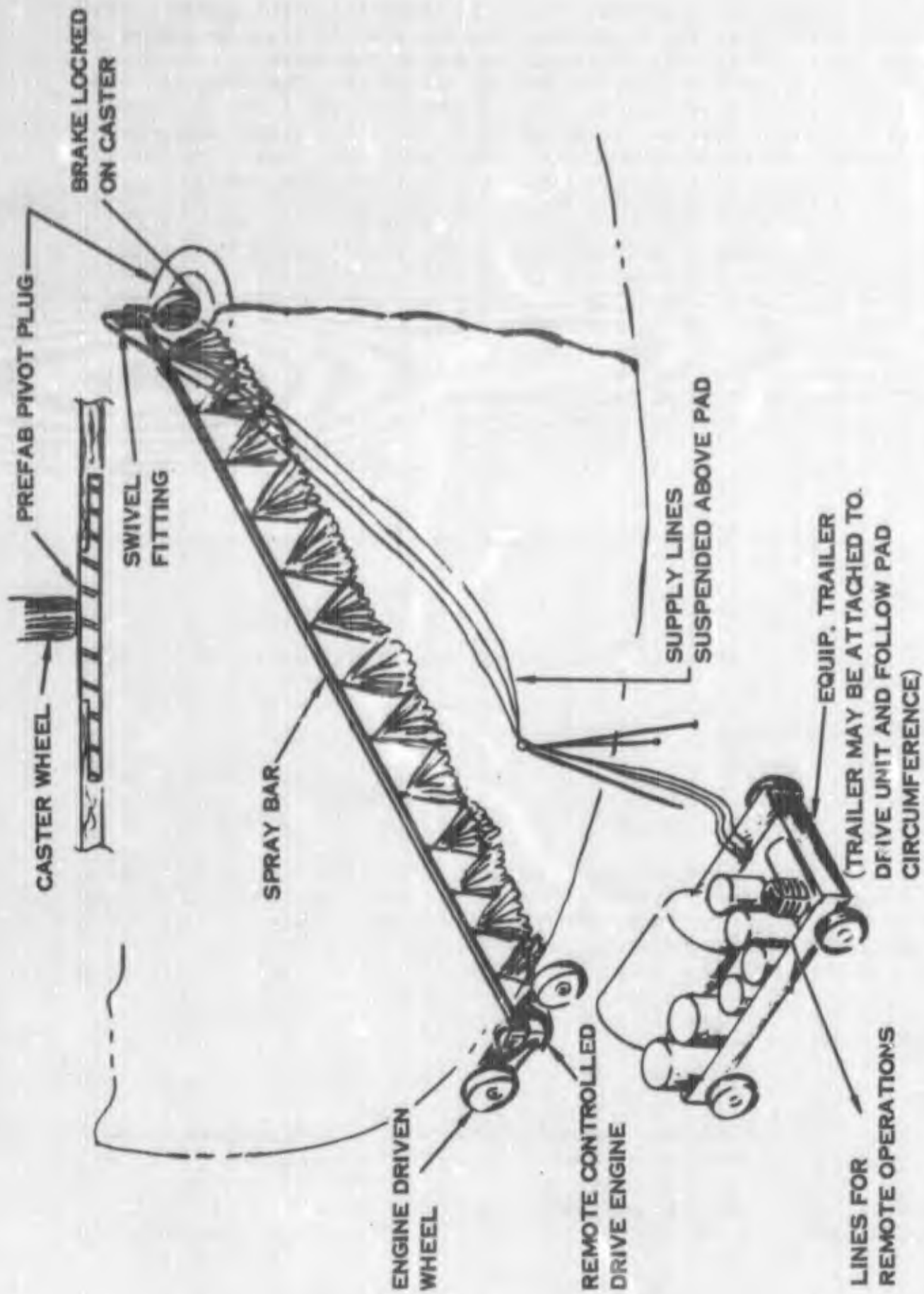


Figure 65. Application Equipment Concept No. 1

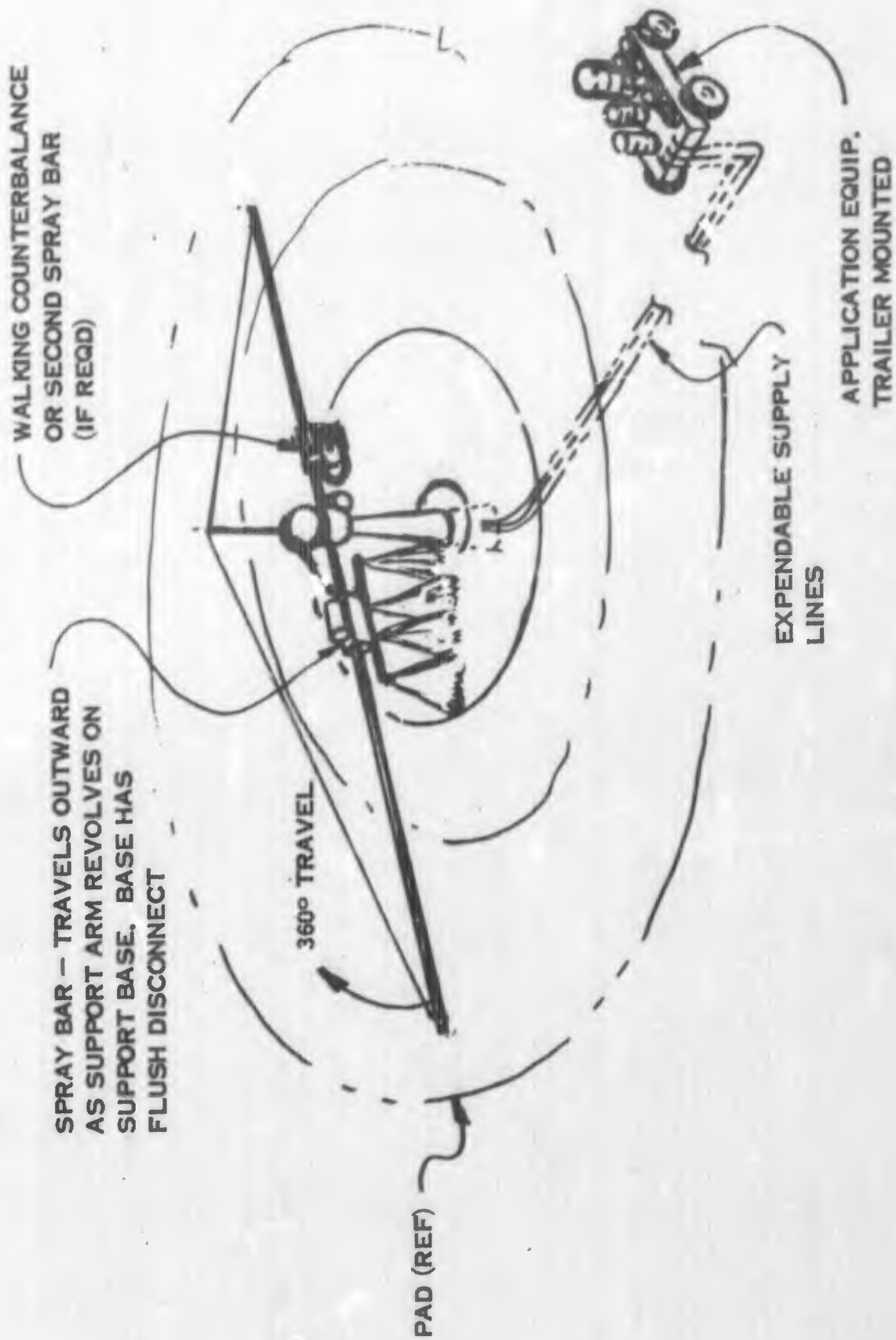


Figure 66. Application Equipment Concept No. 2

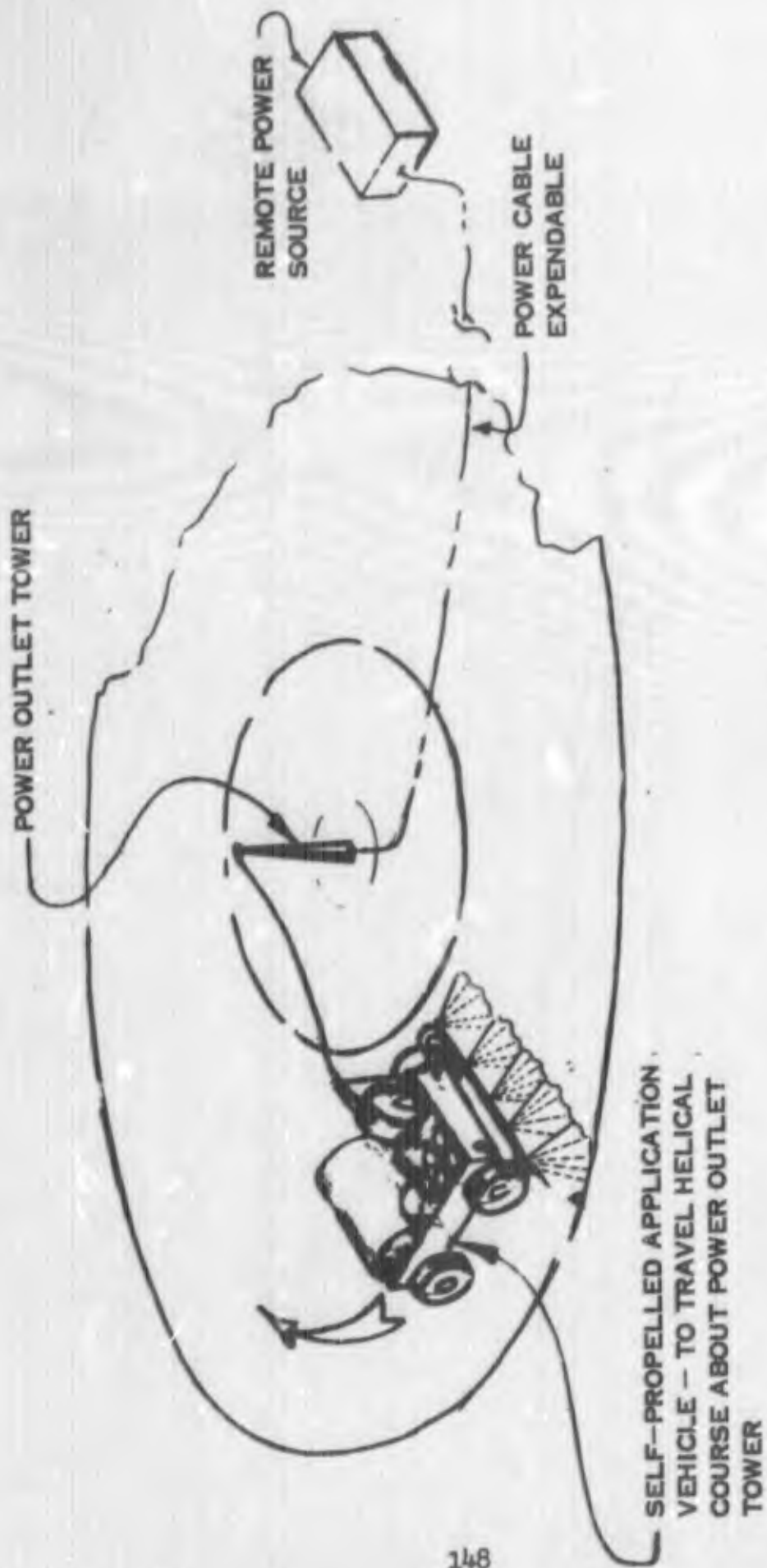


Figure 67. Application Equipment Concept No. 3

Electrical power for driving all systems is suggested to permit the use of an external power source, and to simplify both power and control system routing.

Advantages of this concept include: short plumbing lines; self-contained, except for power and control lines; capable of either remote or direct control; usable with pads of other shapes by changing the programmed or controlled path. Disadvantages include: necessity to drive the unit on the site area (not desired in soft ground because of probability of rutting or otherwise roughening the surface); probable high cost for programmed, mechanized system; probable high weight as a result of using electrical power for propulsion, pumping and control functions.

Concept number three, like the first two concepts, also presents several problem areas or areas that would require considerable analysis and development effort before hardware could be produced. These areas include: development of a multinozzle spray bar, preferably one that was airless to improve efficiency; development of a continuous roving fiberglass dispensing system which is less susceptible to malfunction than the one in use on the Phase I equipment; development of control systems which would reduce the amount of operator control required to set the proportion of glass, catalyst, and promoter ingredients to resin.

e. Concept Number 4

This concept was generated as an improvement over the Phase I system. The handheld nozzles were replaced with an articulated boom with a spray bar mounted on the end of the boom. The bar dispensed both resin and glass.

Figure 68 shows the concept in operation. The boom is attached to the prime mover (same vehicle as the Phase I system) with a joint that provides both rotation and elevation control. Simultaneous movement of the boom's second joint provides reach and height control for the spray bar. A third control input would orient the spray bar relative to the vehicle, permitting application in almost any direction relative to the centerline of the vehicle. An additional change in the vehicle (over the Phase I system) would be the addition of a separate power source for driving the resin pumps and other system elements. This would permit the vehicle to be driven slowly across or around the site during application operations. The boom position would be controlled by a boom operator on the vehicle.

Advantages for this concept include: virtually no set-up time; versatility of use, with no commitment to any particular pad shape; small number of operating personnel; self-contained system, not dependent on external power sources or control systems; adaptable to use with handheld spray guns for touch-up or other operations. Disadvantages include: probable high weight and cost because of a complex boom articulation system; development required (similar to that described for concept number three)

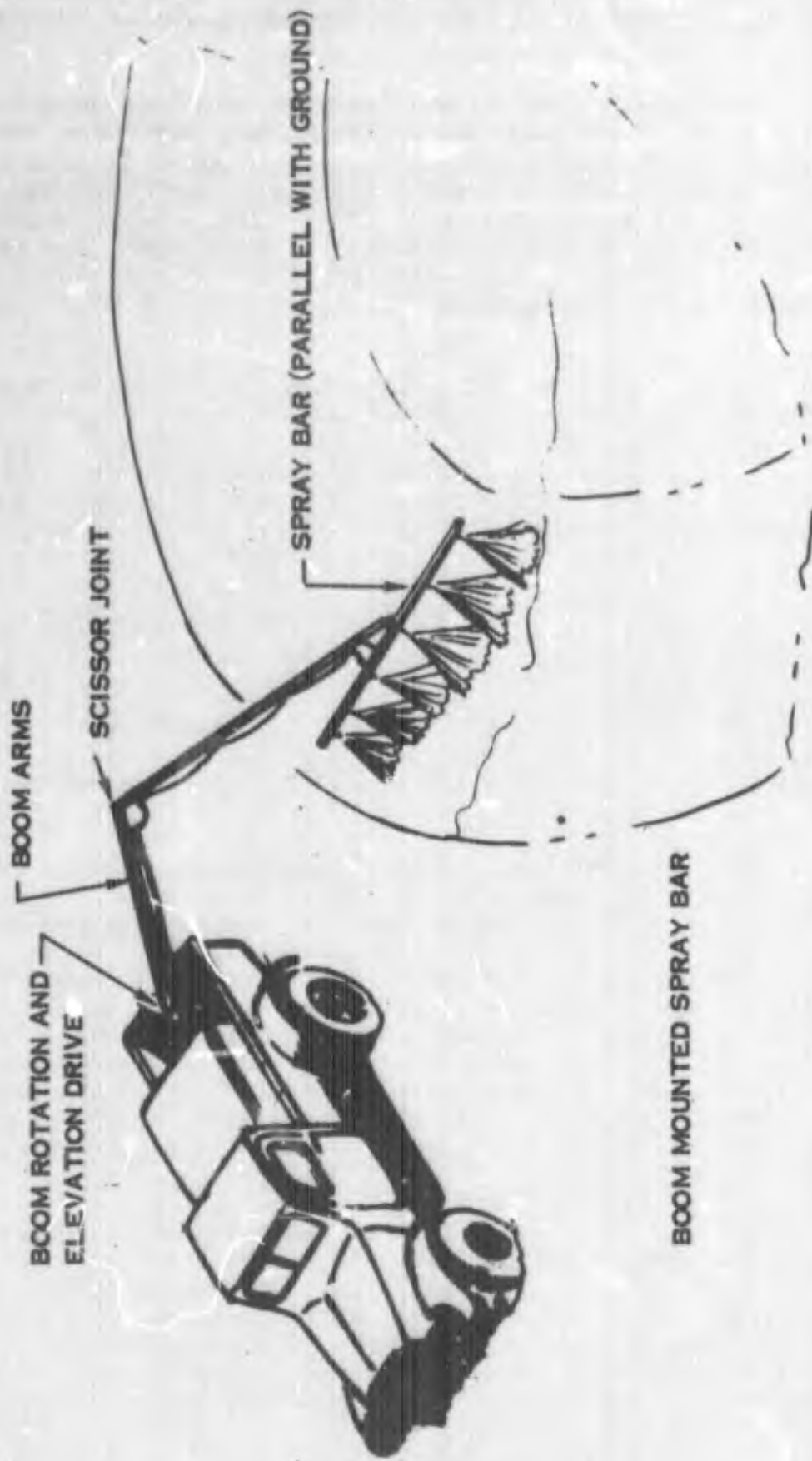


Figure 68. Application Equipment Concept No. 4

on the spray bar; probable overloading of the vehicle by the addition of an engine, the boom, and associated controls. Of course, with regard to the latter item, a similar concept could be incorporated in a larger vehicle.

f. Concept Number 5

This concept, shown in Figure 69, is almost identical to concept number four, but with the spray bar replaced with single large nozzles. This approach would provide the operator with a system less critical with regard to positioning of the structure on which the nozzles are mounted. Other characteristics, and the advantages and disadvantages, are essentially the same as for those of concept number four.

g. Concept Number 6

The objective of this concept was to provide a vehicle-mounted system which could be utilized for application of sites of any shape, with a minimum amount of set-up time, minimum personnel, over level and comparatively smooth terrain, using spray bars attached directly to the vehicle. This concept would necessitate the vehicle's being driven over the site area, but it would permit use of vehicle-mounted spraying equipment, short fluid lines, and consequent minimum weight system.

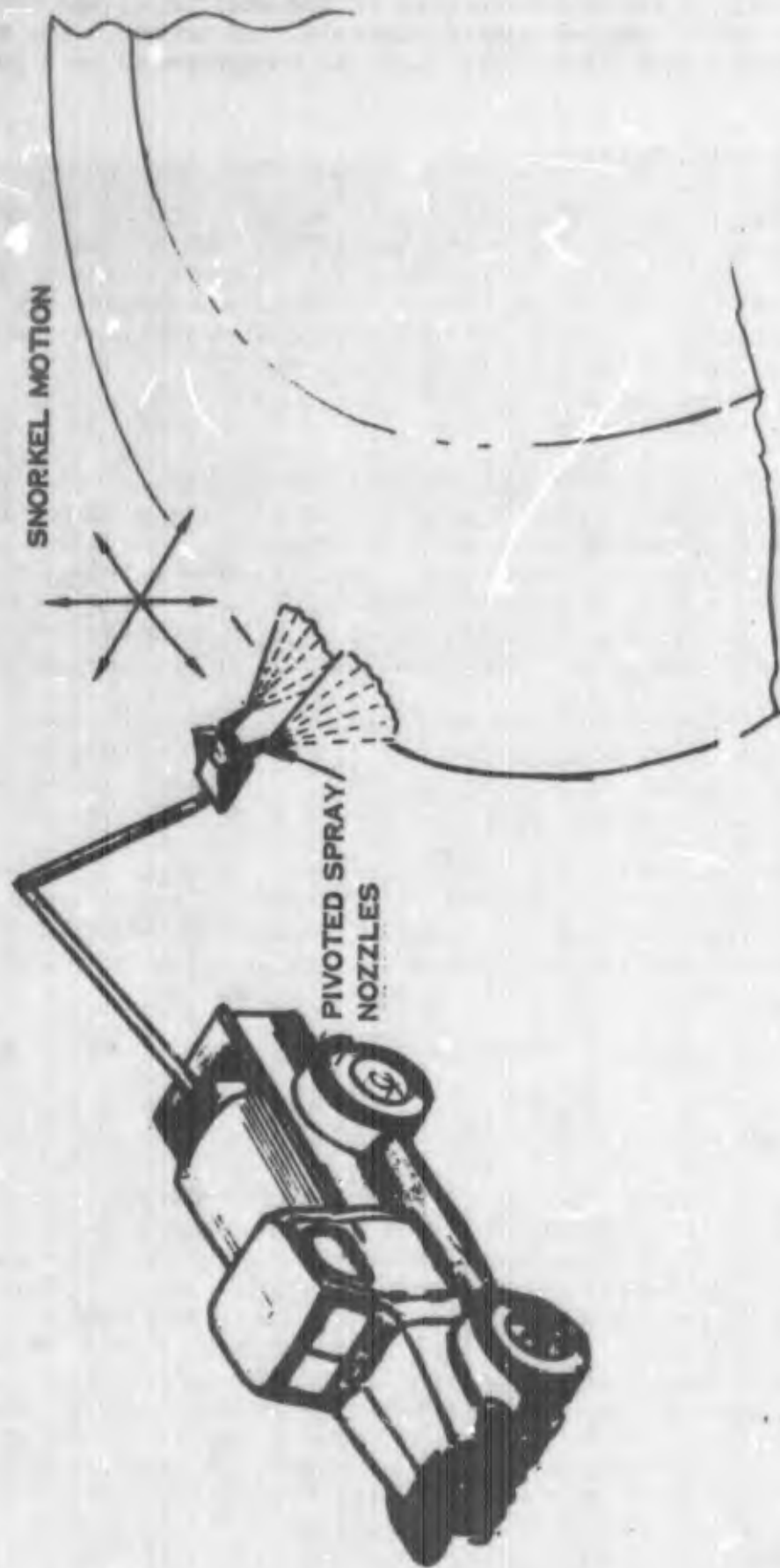
The concept is shown in Figure 70. Dual spray bars, parallel to the direction of movement of the vehicle, were selected, together with a parallelogram mechanism to move the spray bars laterally during operation. This provides full coverage of a rectangular area from the spraying system.

Advantages of the concept include: minimum length plumbing, high mobility possible with the use of a variety of prime mover vehicles, not limited to any particular pad shape. Disadvantages include: probable high cost, development required for multi-nozzle spray bar, width of application area limited by short parallelogram mechanism.

This concept, or variations of it, appears promising for further study.

h. Concept Number 7

This concept was generated to combine the desirable features of concept number one with the features inherent in a vehicle mounted system which traverses the site area. Shown in Figure 71, the concept features a pivoted spray bar mounted on the rear of a prime mover. Elevation of the spray bar would be adjustable to provide for minor variations in terrain. Spray bar rotation about the vertical pivot would be power-driven to provide uniform coverage. Note that total spray bar rotation is limited to about 240 degrees. Application operations would be conducted with the vehicle stationary until a complete 240 degree segment of the site had been sprayed. The vehicle would then be moved forward, and another segment applied, with some overlap of the initial segment. Waste from overlap might be reduced through selective cutting off of fluid flow from nozzles in the overlap area.



TRUCK MOUNTED SNORKEL

Figure 69. Application Equipment Concept No. 5

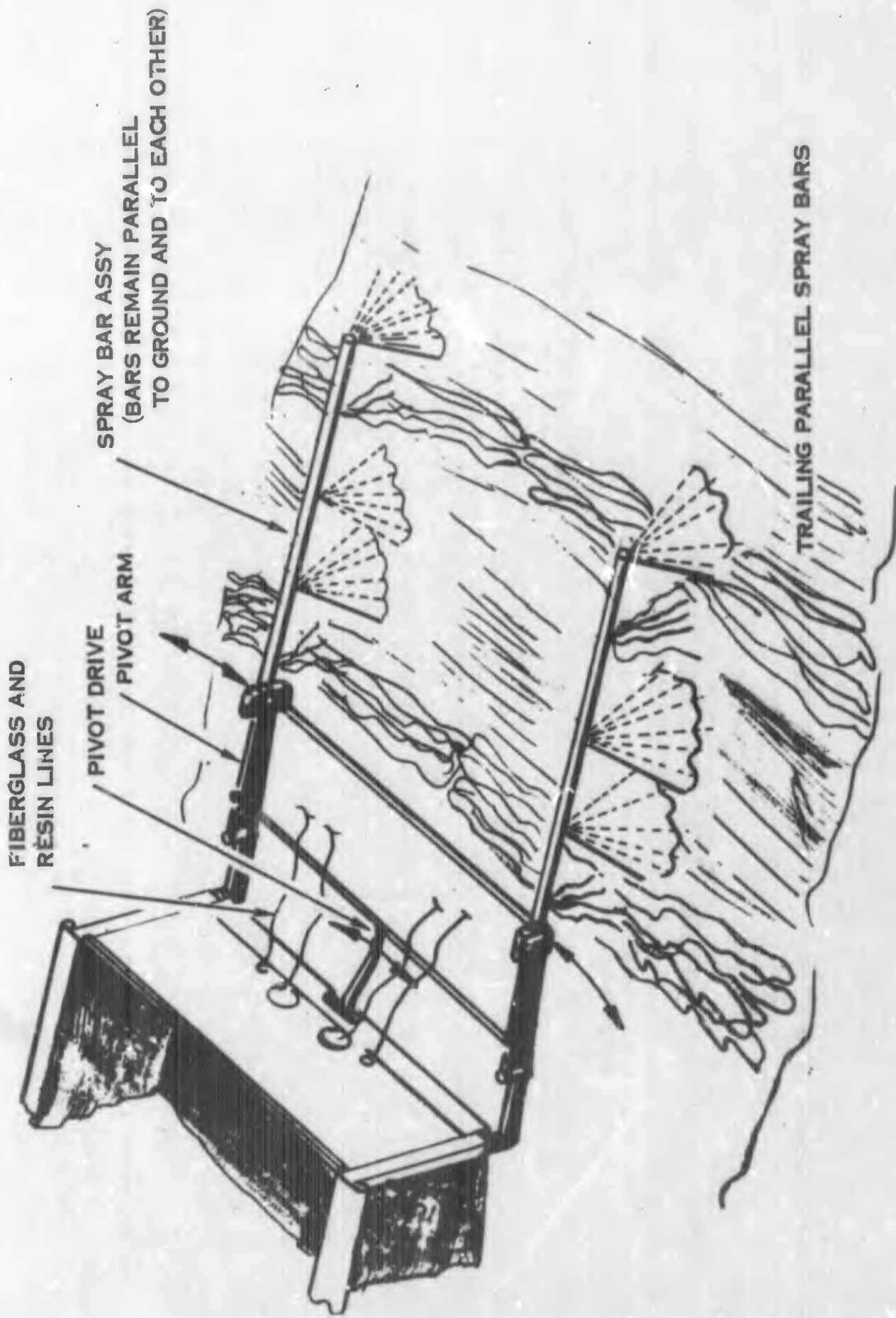


Figure 70. Application Equipment Concept No. 6

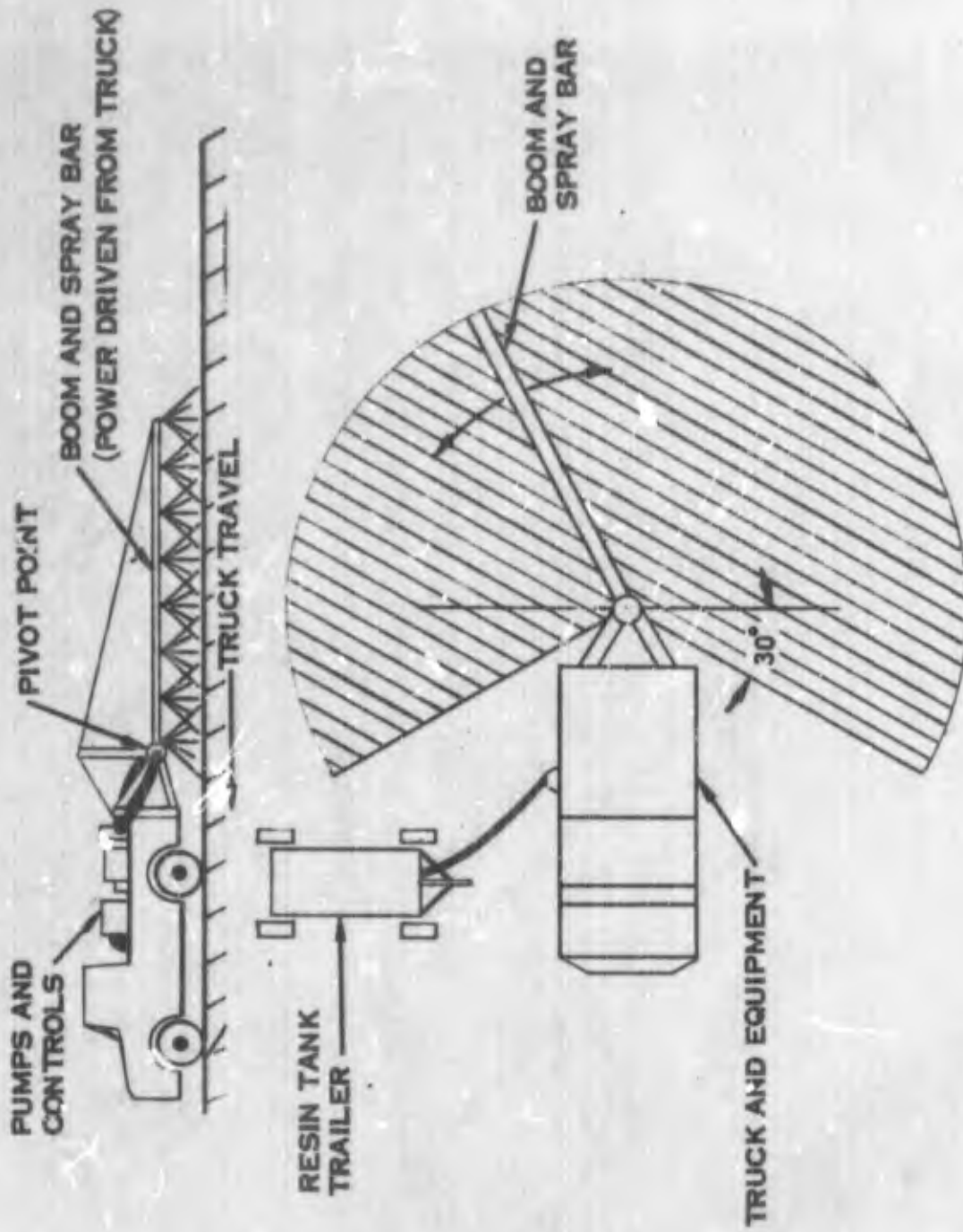


Figure 71. Application Equipment Concept No. 7

Advantages of this concept include: large area coverage, minimum length plumbing, good mobility, minimum set-up time. Disadvantages include: probable high cost, development required for multi-nozzle spray bar, overlap and attendant waste of raw materials, not readily adaptable to touchup operations or spraying small areas.

This concept also appears to warrant further study.

i. Concept Number 8

An alternate concept for number 7 is portrayed in this concept, in which the objective was to eliminate the overlap characteristics of concept number 7. The vehicle is equipped with a track system running parallel to the longitudinal centerline of the vehicle. (See Figure 72.) A transverse spray bar is suspended from this track by a powered trolley. With the truck in a given position, the spray bar can be moved from the rear to the forward limits of the longitudinal track. The vehicle will then be moved forward, while the spray bar is moved aft to its most rearward position on the longitudinal track. This process will be repeated until the desired area is covered. This concept lends itself to the present prime mover which cannot spray and travel at the same time.

Advantages for the concept include: lays rectangular area with no overlap; spray bar output across the spray bar is uniform; provides precise control of pad thickness; lends itself to programmed application. Disadvantages include: probable high cost; high set-up and disassembly time required for travel of the vehicle through close quarters; not readily adaptable to touchup operations or spraying small areas.

This concept, like concept number 7, appears to warrant further study.

j. Concept Number 9

This concept was another one generated to examine possible improvements to the first order Phase I equipment. In particular, it was based on the possible use of the equipment for preparing large sites approximately 250 feet in diameter. For a site of this size, it would be necessary to traverse the site with the prime mover, rather than placing the prime mover at various positions at the periphery of the site, since hoses of 125-length would be prohibitively large and heavy.

Since the prime mover would be traversing the site, the concept chosen was one in which support booms would be added to support the resin and glass hoses, as shown in Figure 73. This would permit rapid movement of the vehicle from spot to spot during application operations, and would also reduce operator fatigue. To minimize numbers of operations personnel, the use of a multi-nozzle spray bar was suggested, permitting one operator to apply resin. In like manner, a single operator was employed to apply glass, using a multi-nozzle dispenser mounted on the second boom.

FOR CIRCULAR SITES,  
MATERIAL UTILIZATION IS  
LESS THAN 100 %.

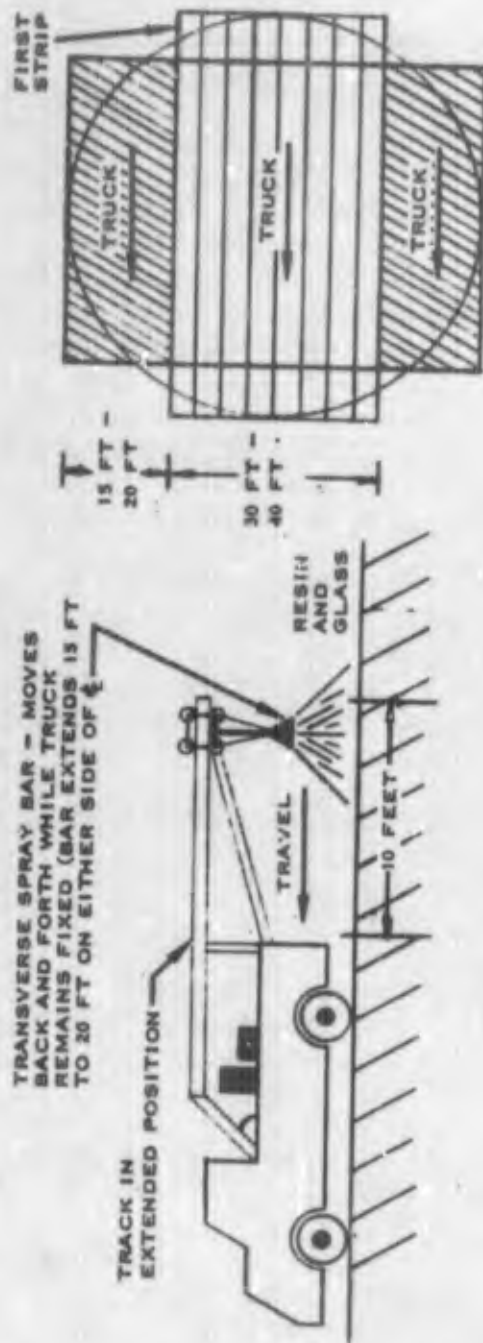
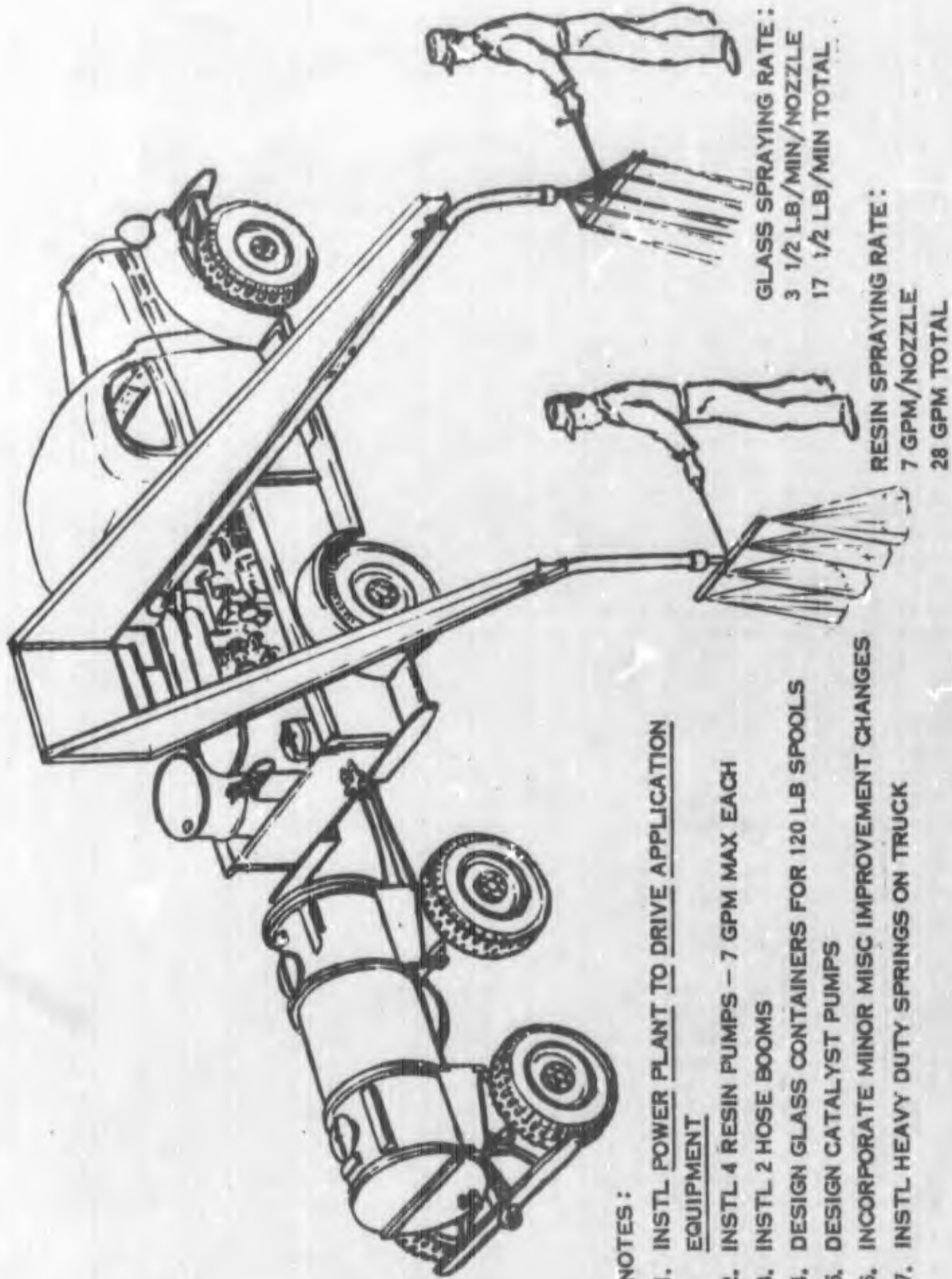


Figure 72. Application Equipment Concept No. 8



**NOTES :**

1. INSTL POWER PLANT TO DRIVE APPLICATION EQUIPMENT
2. INSTL 4 RESIN PUMPS - 7 GPM MAX EACH
3. INSTL 2 HOSE BOOMS
4. DESIGN GLASS CONTAINERS FOR 120 LB SPOOLS
5. DESIGN CATALYST PUMPS
6. INCORPORATE MINOR MISC IMPROVEMENT CHANGES
7. INSTL HEAVY DUTY SPRINGS ON TRUCK

Figure 73. Application Equipment Concept No. 9

Modifications to the application system also included the installation of larger resin pumps, increasing the spray rate to 28 gallons per minute. The site assumed for the operation was of the following characteristics:

Diameter	250 feet
Density	4 lb/sq ft for 100-foot diameter 2 lb/sq ft for balance of site
Resin	B-3-B, 11 lb/gallon
Total Resin, Weight	113,000 pounds
Fiberglass	Continuous End Roving, 5% of resin by weight of 5650 pounds total
Actual Spraying Time	$113,000 \div (28 \times 11) = 334$ minutes = 5.6 hours

Other modifications to the Phase I equipment which would be required to accommodate the above site application include the addition of a pumping system for transfer of the resin from shipping drums to the tank trailers, since four 400-gallon tank trailers would not be adequate for the entire site without refilling.

Advantages of the concept include: accommodation of large site size with minimum change to existing system; adaptable to a variety of site sizes and shapes; reduced operator fatigue; reduced time required for preparation to move. Disadvantages include: increased weight on the vehicle, possible overload condition impending; development required for multi-nozzle spraying systems; need for additional storage caused by the addition of two support booms; possible rutting or grooving of the site from the vehicle tires; probable high cost of lightweight booms. (Note: The possible use of a hose support boom appeared so promising that the design and fabrication of a test unit was completed during the Phase I program. For additional details see paragraph j, page 132.)

This concept, possibly with a larger vehicle or one with a higher payload, warrants further study.

k. Concept Number 10

In view of the possible overloading of the vehicle in concept number 9, this concept was generated as a scheme by which mechanized application might be performed with the same basic prime mover. In addition, the concept offered a method of transporting the fiberglass for the pad on the application system, rather than transporting it separately as on the Phase I equipment. This would eliminate the time spent in transferring the glass to the application system.

This concept is shown in Figure 74. The Phase I prime mover is used as the towing vehicle, modified to increase the resin pumping rate, and with a separate engine added to drive the air compressor and the resin pumps. The addition of the separate engine allows the vehicle to be moved at a constant rate during application operations. The resin

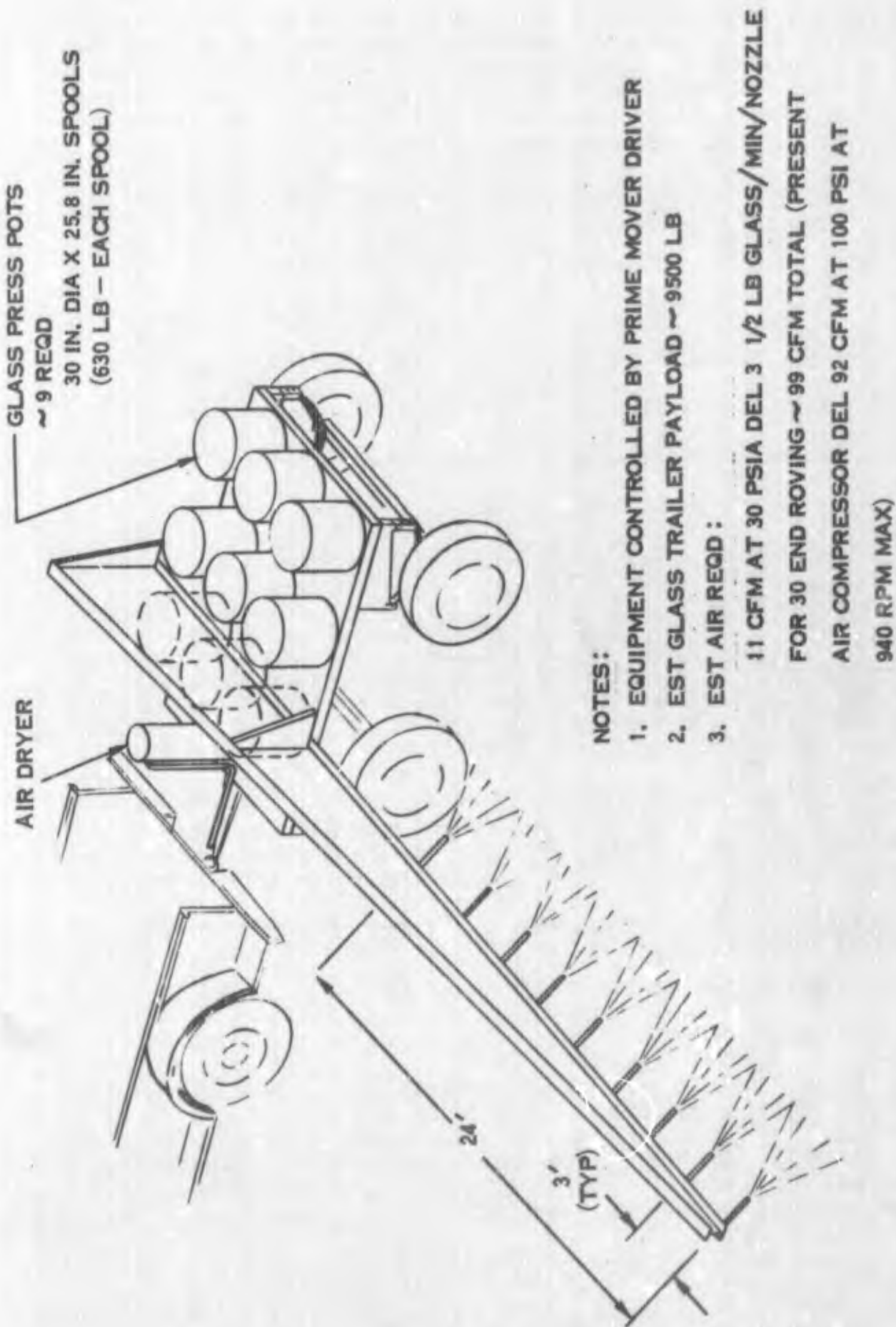


Figure 74. Application Equipment Concept No. 10

and glass are dispensed from a spray bar mounted on the trailer shown in figure 74. The trailer also transports several large glass pots, each feeding a glass nozzle on the spray bar. The glass pots are reloaded at less frequent intervals than those used on the present Phase I equipment because of their multiple number and their large size. Requirements for the systems for this concept were as follows:

Total Resin	113,000 pounds
Total Glass	5% of resin by weight or 5650 pounds
Resin Spray Rate	56 gallons per minute
Glass Spray Rate	31½ pounds per minute
Actual Spray Time	3 hours, approximately
Spray Rate per Nozzle	(Glass) 3½ pounds per minute
Number of Glass Pots Required	9
Amount of Glass per Pot to Eliminate Reload during Operation	630 pounds

Assuming that each glass nozzle covers an area 3 feet wide, the spray bar would be 24 feet long. Prime mover vehicle velocity during spray operations would be approximately 0.06 miles per hour. (Use of a dual 12-foot spray bar would increase the vehicle velocity to 0.12 miles per hour).

Advantages of this concept are: increased performance of the Phase I system without overloading the prime mover vehicle; addition of a mechanized system without eliminating the handheld system; elimination of glass reload during the application operation. Disadvantages include: probable high cost; need to add an engine, and perhaps a larger capacity air compressor to the present vehicle; increased set-up time induced by connection of resin and air lines between prime mover and the trailer.

Variations of this concept warrant further study.

#### 1. Concept Number 11

The objective of this concept was to provide a single-vehicle, highly mechanized system capable of applying a 250-foot diameter site without reload of any materials. The vehicle would transport all of the resin, glass, and catalyst for the entire site, and would perform the operations with a minimum number of personnel. The following data was assumed for the materials to be applied:

Resin	113,000 pounds (10,000 gallons)
Fiberglass	5% by weight of resin or 5650 pounds (continuous roving)
Catalyst	1 1/2% by weight of resin or 1500 pounds
Application Time	3 hours or less, permitting site to be laid out and applied in one day with adequate allowance for cleanup

Preliminary estimated payload weight for a system meeting the requirements was as follows:

	<u>Pounds</u>
Resin	113,000
Resin Tank	25,000
Resin Pump	5,000
Fiberglass	5,650
Glass System	3,000
Catalyst	1,500
Plumbing and Miscellaneous	<u>1,000</u>
Total	154,150

A large wheeled vehicle was assumed for transport of the above payload, with a 1:1 ratio of vehicle to payload weight. Suitable wheel systems, among those currently available, are the LeTourneau Electric Wheelsmith, 120-inch diameter, 54 psi, rated at 84,000 pounds each.

This concept is shown in Figure 75. The resin is contained in an elliptical cross section tank, 5 feet high, 12 feet wide, 28.5 feet long. The catalyst tank is 36 inches in diameter, 43 inches high. The fiberglass container, while not defined as to specific method of operation, is 54 inches in diameter by 36 inches long, two required.

Total estimated weight of the system is 346,000 pounds, which would limit the transportability of the system to railroad and large aircraft of C-5A size. For transport by other means, disassembly of the system would be required.

The dispensing system is mounted on a remotely-controlled, hydraulically-actuated articulated boom, and terminates in two large nozzles, one for resin and the other for glass. To maintain the nozzles at a constant height above the terrain during operations of reaching or traversing, the control system would be closed loop and programmed to provide the proper interaction between control cylinders. Trim controls would be provided to permit initial orientation and height settings of the nozzles to the terrain.

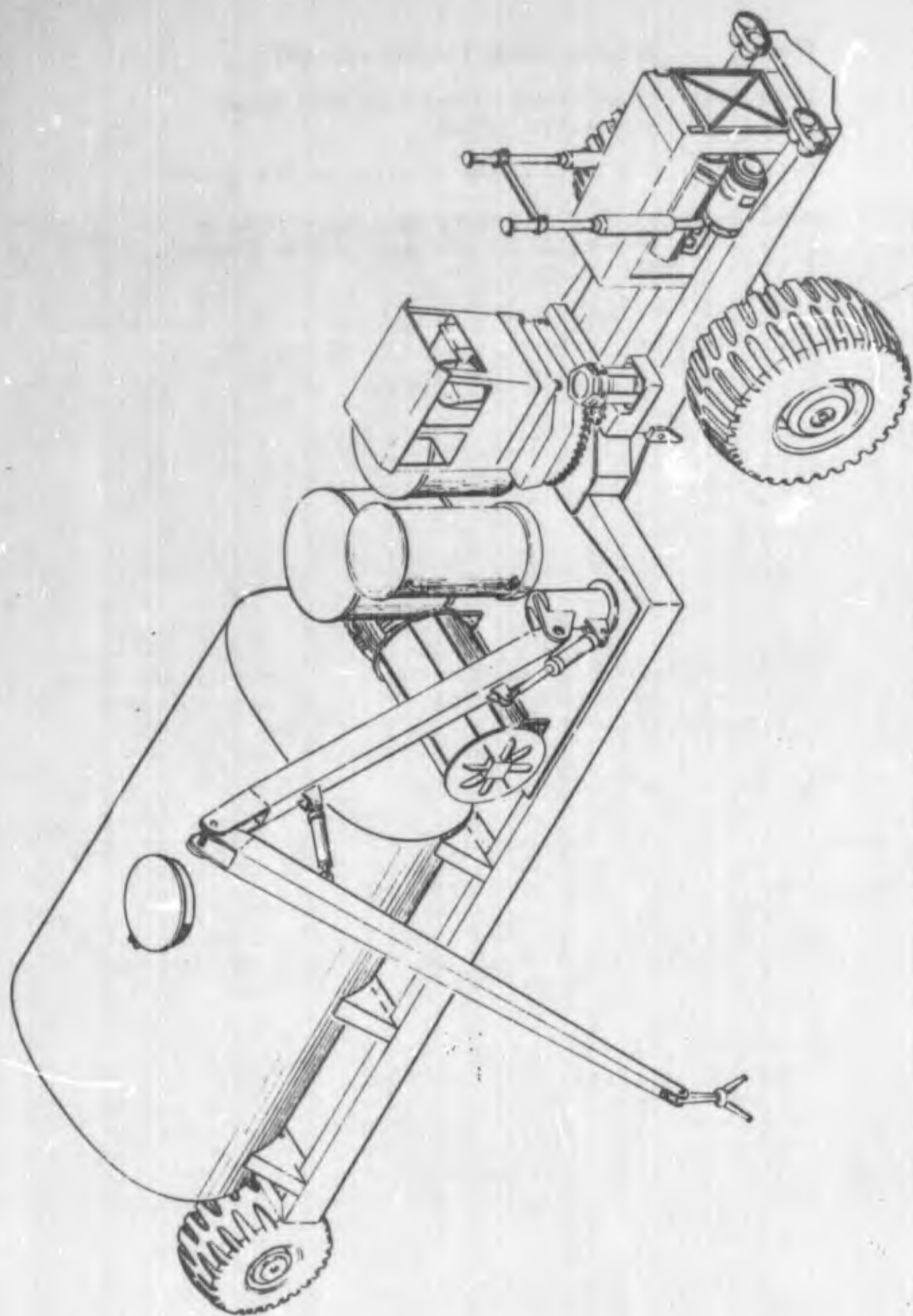


Figure 75. Application Equipment Concept No. 11

Advantages of the concept include: only one vehicle required; inventory of materials is simplified; all materials are preloaded, reducing time and personnel for reload during operations; system is adaptable to touchup operations or applications to surfaces other than horizontal. Disadvantages include: extremely large size of vehicle makes transport difficult; not economical for use on small sites.

No further study of a single system this large is recommended.

m. Concept Number 12

This concept was generated to provide many of the advantages of previous concepts, within a framework of improving the performance of the Phase I system and providing a system of reasonable cost, adaptable to a variety of transporting vehicles. Adaptability to several vehicles suggested that the system be self-powered and mounted on a frame or pallet which could be mounted in trucks, trailers, or tracked vehicles. The pallet could also be transported by helicopter or cargo aircraft if within size and weight limits. To evaluate the feasibility of the approach, a space layout of increased detail over previous concepts was generated, as shown in Figure 76.

The pallet mounted system includes the engine and all components for applying and controlling application rate of the resin, catalyst, and fiberglass. All materials except resin are contained on the pallet. (Fiberglass reload is required.) The resin would be transported on an adjacent vehicle in pallet mounted tanks to provide versatility of vehicle selection also.

Maximum resin spray rate of 28 gallons per minute, to permit applying 113,000 pounds of resin within 6 hours of actual spraying time.

The pallet includes a boom, the center support for which is shown in Figure 76. However, this could be replaced with a spray bar system if desired.

Preliminary selections of functional components are shown in the material list on Figure 76, together with estimated weights. The pump shown is a multi-stage screw pump, capable of providing 225 psi. Should the resin nozzle require higher pressure, the pump selection would be modified to include additional stages.

Advantages of the concept include: adaptability to various transport vehicles; adaptability to handheld and mechanized spraying systems; reasonable size, compatible with transport and logistics problems; self-powered, eliminating dependency on transport vehicle powerplant and permitting transport vehicle to traverse site during application. Disadvantages include: weight penalty of pallet over an integrated system which is supported by the transport vehicle chassis.

QTY	ITEM DESCRIPTION
1	WISCONSIN ENG #V461D
1	WISCONSIN CLUTCH & GEAR BOX
1	BINKS AIR COMPRESSOR #33-5
1	RESIN PUMP MOYNO #3MB
1	CATALYST PUMP MOYNO 2ML
1	VARIABLE SPEED DRIVE HI-LD
4	GLASS POT (W/O GLASS) @ 125"
1	CLUTCH (AIR COMPR)
1	CLUTCH (PUMP DRIVE)
2	COUPLING (LARGE SHAFT)
1	COUPLING (SMALL SHAFT)
4	SHEAVES (SIZE UNKNOWN)
1	BATTERY 12 VOLT
1	SOLVENT POT 20 GAL
1	CATALYST POT 100 GAL
1	AIR RECEIVER
1	CONTROL PANEL
~	MISC. HARDWARE & PLUMBING

EQUIP TOTAL

ESTIMATED PALLET WT  
 EST SPRAY BOOM & SUPPORT  
 EST SPRAY HOSES & NOZZLES

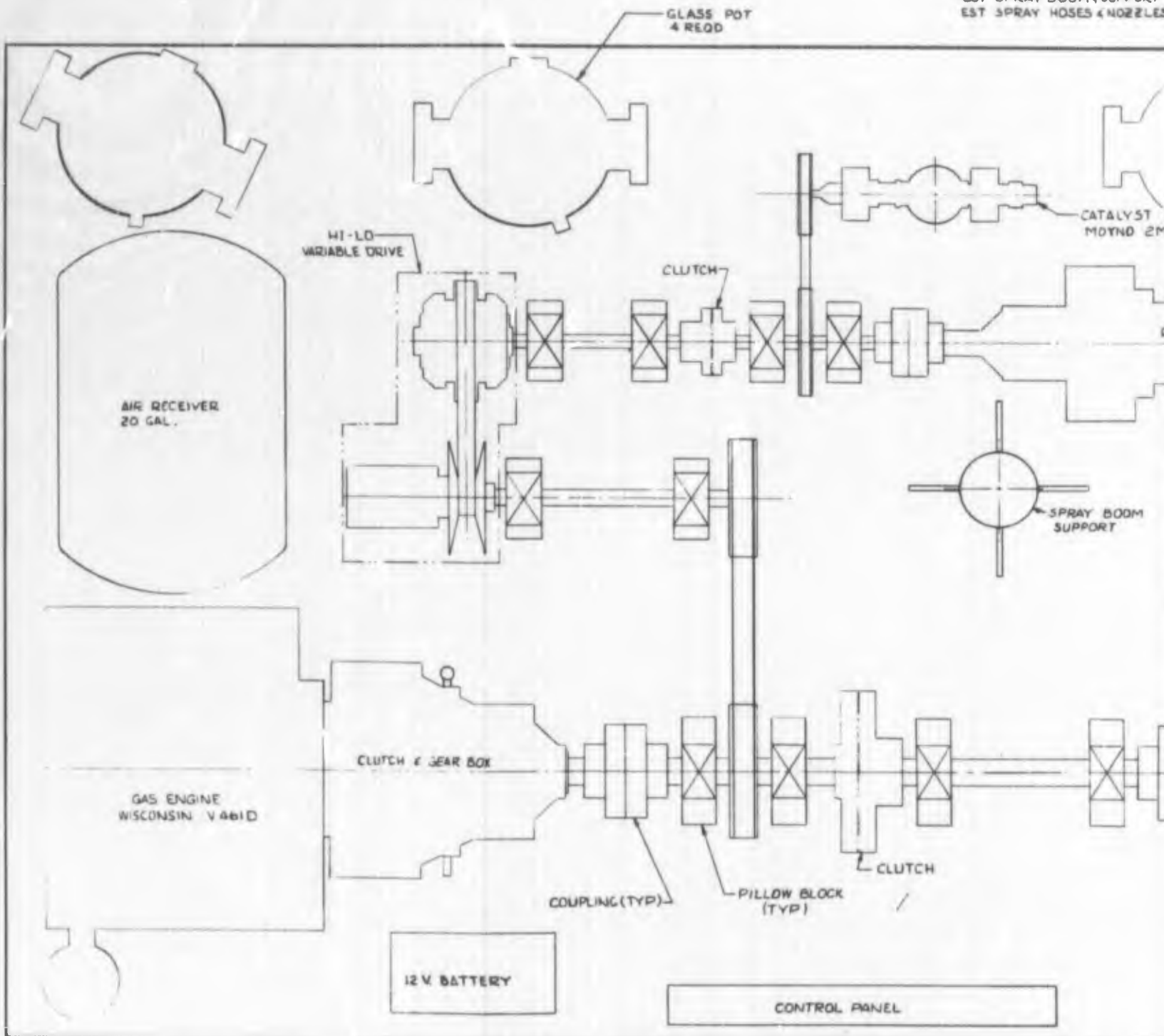
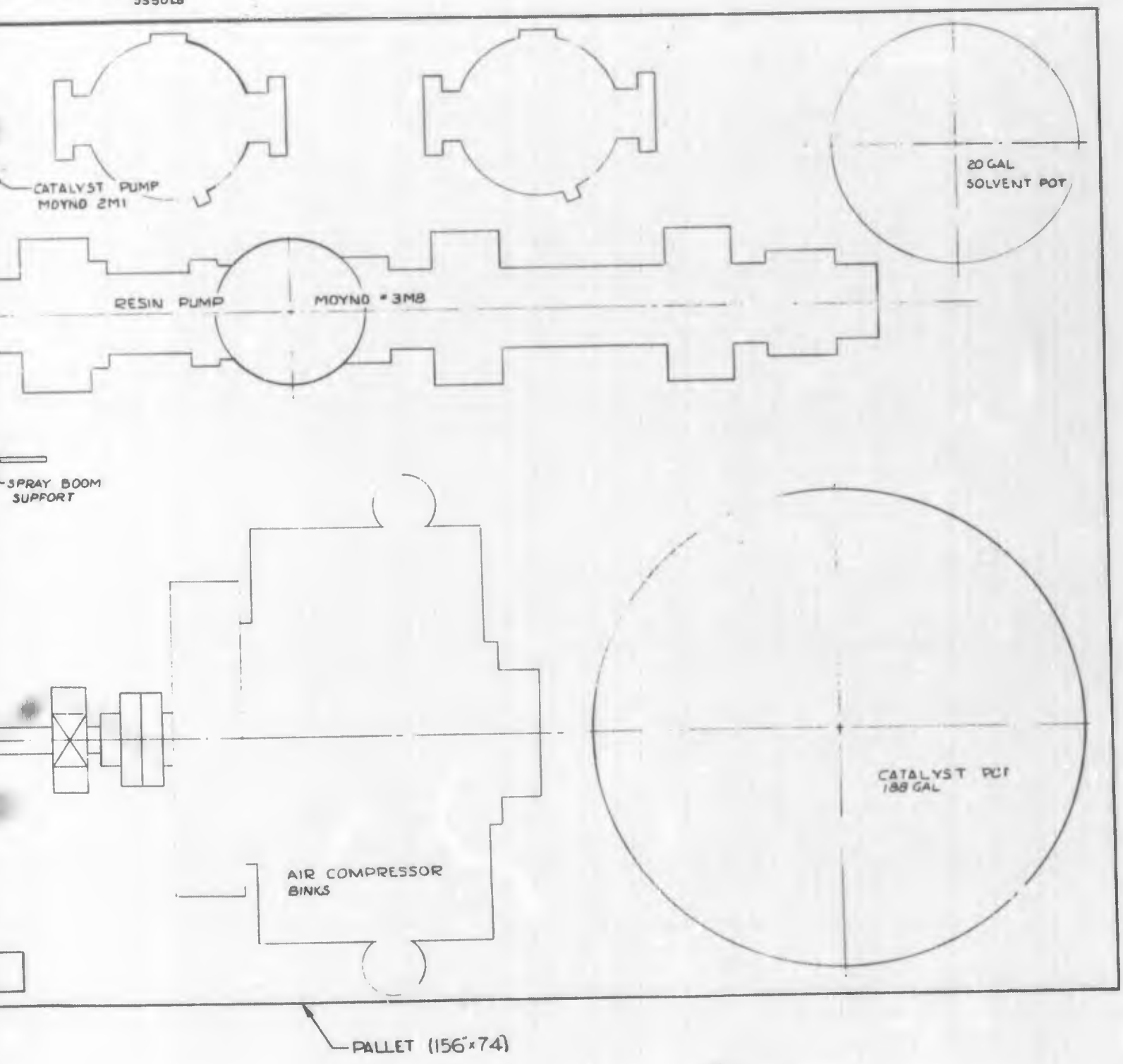


Figure 76. Application Equipment Concept Number 12

DESCRIPTION	TOTAL WEIGHT
1" V461D	320
1" V461D	220
1" V461D	950
1" V461D	545
1" V461D	25
1" V461D	50
1" V461D	500
1" V461D	25
1" V461D	10
1" V461D	30
1" V461D	5
1" V461D	30
1" V461D	30
1" V461D	120
1" V461D	200
1" V461D	70
1" V461D	50
1" V461D	250
EQUIP TOTAL	3650
PALLET WT	1400
BOOM & SUPPORT	100
HOSES & NOZZLES	200
	3350LB



B

Figure 77 shows an alternate configuration of concept number 12. This system, also palletized, is based on the use of dual Viking pumps, and is considered more adaptable to handheld operations than the system of Figure 76. Two operations would be utilized for resin spray operations, similar to the Phase I equipment system. For mechanized operations with a spray bar, the output from the two pumps would be directed through a manifold.

Further study of these or similar palletized concepts is recommended. Additionally, further study is recommended to determine the optimum application rate for the system.

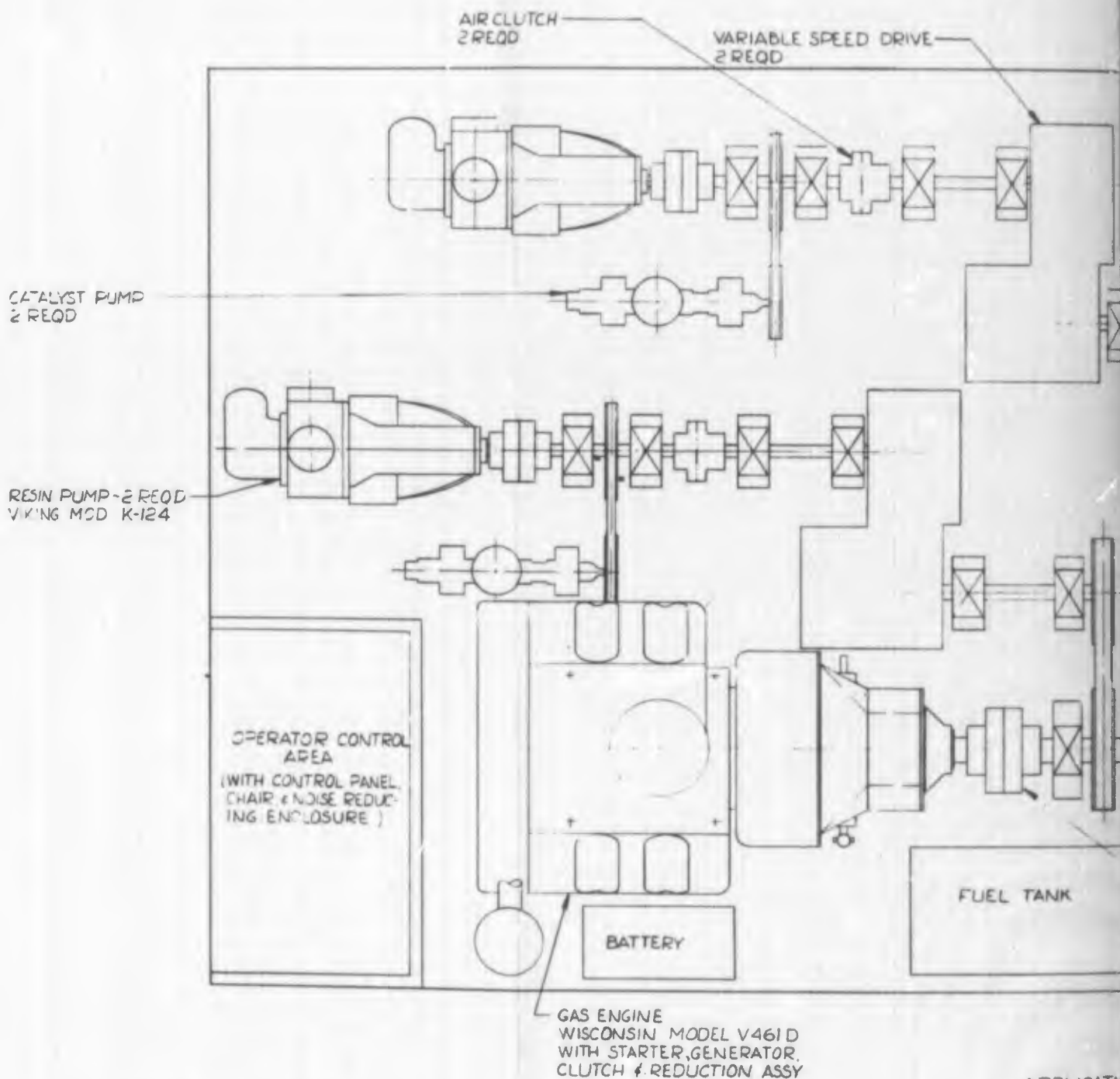


Figure 77. Application Equipment Concept Number 13

A

QTY	ITEM DESCRIPTION	TOTAL WEIGHT
1	WISCONSINENS PWD D	520
1	CLUTCH & REDUCTION ASSY	220
1	BINKS COMPRESSOR 33-561	850
2	RESIN PUMP-VIKING K-124	220
2	CATALYST PUMP	80
2	VARIABLE SPEED DRIVE	100
4	GLASS POT (W/O GLASS) 4 1/2" DIA	340
1	CLUTCH (AIR COMP)	25
2	AIR CLUTCH (PUMP DRIVE)	20
1	COUPLING (ENG SHAFT)	15
1	SPECIAL COUPLING	15
2	COUPLING (PUMP SHAFT)	10
8	SHEAVE (SIZE UNKNOWN)	60
4	V-BELT (SIZE UNKNOWN)	10
1	BATTERY - 12 VOLT	50
1	FUEL TANK	25
1	SOLVENT POT 15 GAL	85
1	CATALYST POT 60 GAL	125
1	AIR RECEIVER	70
~	MISC-HARDWARE & PLUMBING	300

EQUIP. WEIGHT 3270

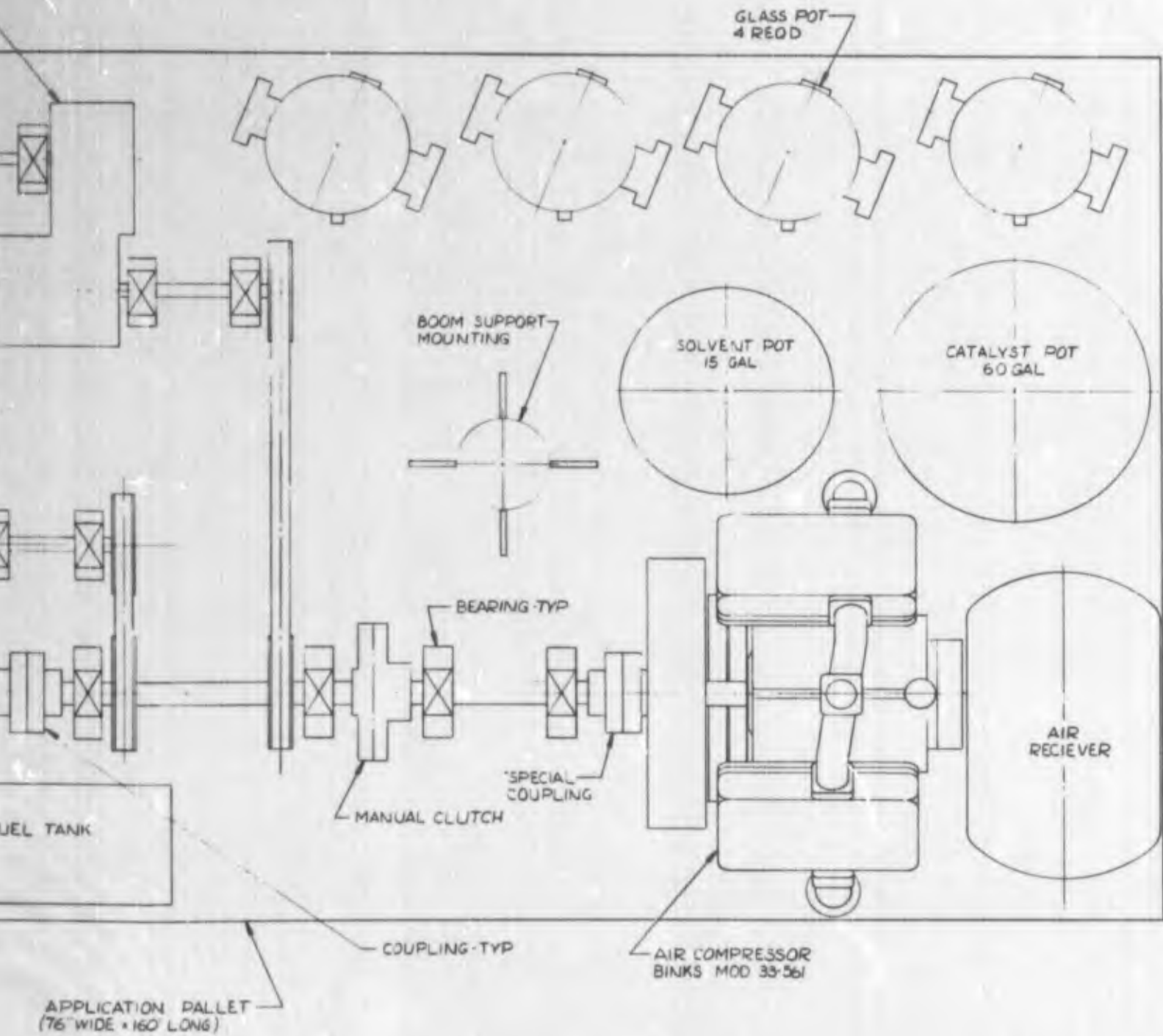
1 OPERATOR STATION 400

2 EST. PALLET WEIGHT 1300

3 EST. SPRAY BOOM & SUPPORT 180

4 EST. NOSE & NOZZLE 300

5720 LB



B

## SECTION IV

### SITE DESIGN REQUIREMENTS

#### 1. SITE THICKNESS CRITERIA

A program of simulated aircraft wheel load tests on rapid site pads over selected soils was initiated to determine the relationship of the applicable variables to the allowable wheel loads.

##### a. Purpose of Tests

The rapid site landing pads should be constructed to the minimum thickness that will support the applied aircraft and ground vehicle loads without pad material failures or excessive deformations, in order to minimize material costs, material shipping costs, logistics problems, and spraying time. The variables affecting the landing pad wheel load capability are:

Wheel (Tire) Contact Pressure

Tire Inflation Pressure

Soil Properties

Landing Pad Thickness

Allowable Stresses in Pad Material

Flexibility (Modulus) of Pad Material

In summary, the purpose of the wheel load pad tests are:

(1) To develop, from the test data, an empirical site (pad) thickness design criteria.

(2) To provide pad material composition evaluation data.

(3) To reveal unforeseen problem areas in rapid site pad design construction.

##### b. Test Equipment and Procedures

An overall view of the initial load test facility is shown in Figure 78. The test soil is packed into the steel retaining tank, which is 15 feet in diameter and 5 feet deep. A hydraulic load cylinder, installed vertically, is designed to provide a maximum load of 60,000 pounds. The lower end of the loading strut will accept both single and dual wheel configurations, and the ram used for soil modulus measurement. A load cell connected between the hydraulic cylinder and the support structure measures the applied wheel load. The test tires are taken from an operational fighter aircraft main landing gear and are comparable to those used on the P.1127 and VJ101C-X2 VTOL airplanes.

Two major modifications were made on the load test facility during the program. Rows of vertical scales were used during the first test to measure the vertical deflection at intervals along the pad. It was found that these readings were negligible three inches beyond the edge of the tire. Therefore, the scales were removed for the remaining tests and only vertical deflections at the center of the pad were measured. Three additional loading points were added in accordance with Contract AF33(615)-3631 (Rapid Shelter Flooring and Helicopter Landing Sites). Figure 79 shows an overall view of the modified load test facility.

All soil preparation for the wheel load tests performed during this testing period was supervised by Mason-Johnston and Associates, Consulting Soil Engineers. These consultants did all the basic soil testing, except for the "Ram" test used to determine soil modulus. The preparation and testing of the soil by engineers knowledgeable in soil mechanics insures that controlled and known soil conditions are maintained. All soil testing was performed in accordance with the criteria set forth by the U.S. Air Force on the design of flexible airfield pavements (see Reference 5).

The soil selected for the first series of wheel load pad tests (Soil No. 1) was "desert sand." This particular soil was chosen because its load carrying capability could be varied considerably, and because it was readily available. Soil No. 2 was "washed sand" because of its similarity to the soil found at Eglin Air Force Base, Florida. Figures 80 and 81 show the pertinent results of the laboratory soil classification and compaction tests. Details of the test procedures, terminology, and discussion of results can be found in Reference 5. Photomicrographs of the two soils are shown in Figure 82.

Each soil was packed into the retaining tank in approximately 12-inch layers. The compaction was done with a gasoline-powered tamper, as shown in Figure 83. During the compaction of Soil No. 1, water was sprayed on the soil at each interval to give a controlled amount of moisture. This was supervised by the soil consultant who made periodic moisture content and density checks with radiation instruments. These instruments are shown on the right of Figure 83. The density measuring device emits gamma radiation which is reflected back by the soil in direct relation to the soil's bulk density. The moisture measuring device emits neutrons which are reflected back by the water molecules in the soil. These instruments permit rapid, accurate evaluation of soil moisture and density. Soil No. 2 was compacted in a similar way but no moisture was added. The surface of the sand was smoothed and leveled by scraping with a long straight edge that spanned from rim to rim of the retaining tank. After each test, the soil in the vicinity of the loading point (approximately 5 feet in diameter and 2 feet deep) was dug up and recompactd to its original state.

The landing pad material was applied to the level surface of the soil. Figure 84 shows the spraying operation; one operation was applying the fiberglass and the other was covering it with resin. Each pad is designated as follows in the order that they were tested: 1,2,3, 4,1R,2R,2 1/2R-1, 3R,5,6,7 and 8. Pad tests No. 1 through No. 3R were performed on Soil No. 1 and the remainder on Soil No. 2.

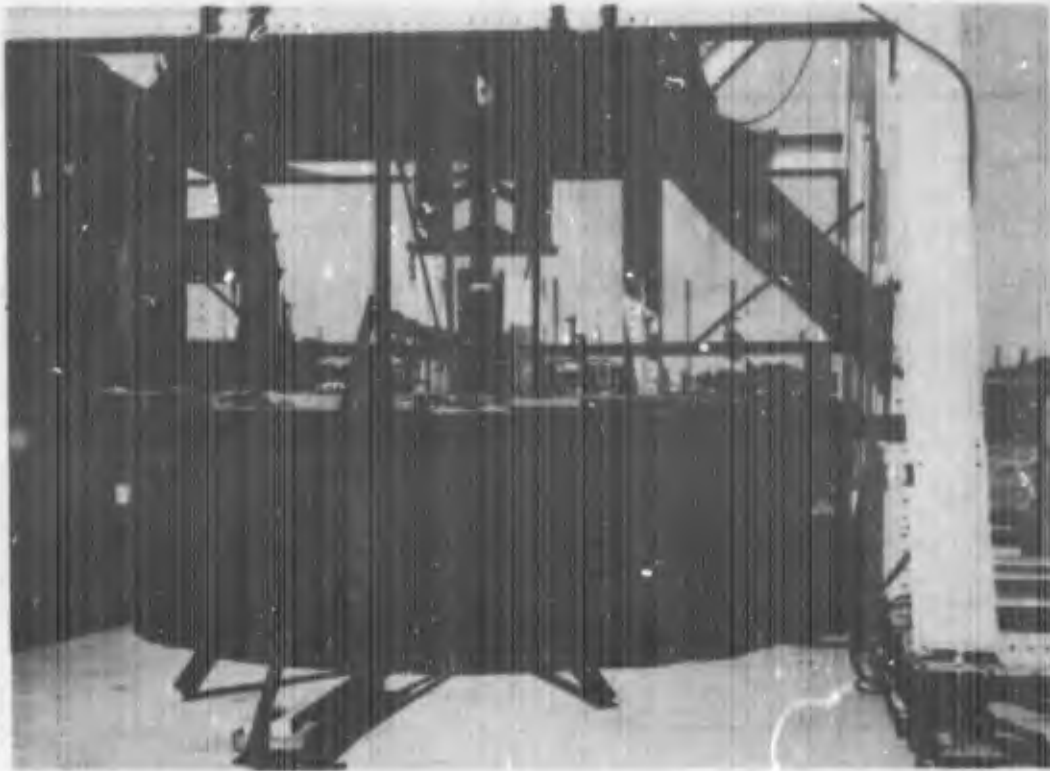


Figure 78. Wheel Load Pad Test Facility - Before Modification

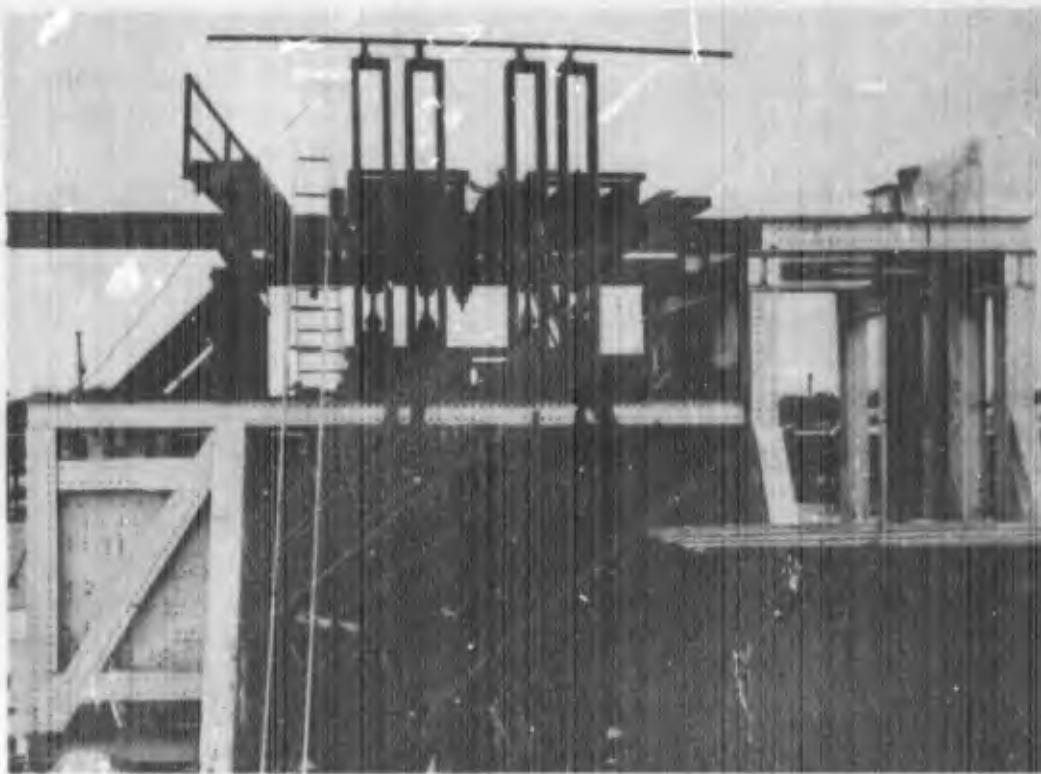
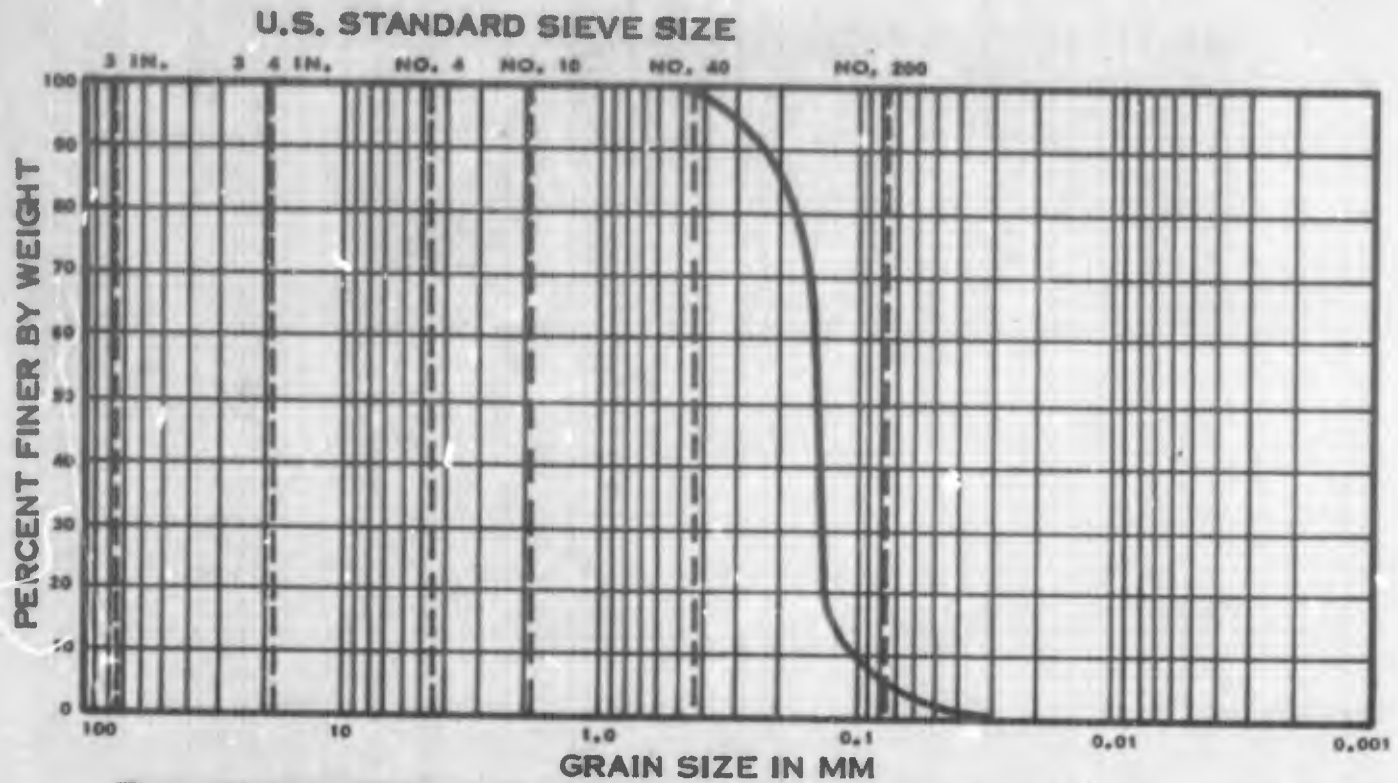


Figure 79. Wheel Load Pad Test Facility - After Modification



GRAVEL		SAND			SILT OR CLAY
COARSE	FINE	COARSE	MEDIUM	FINE	

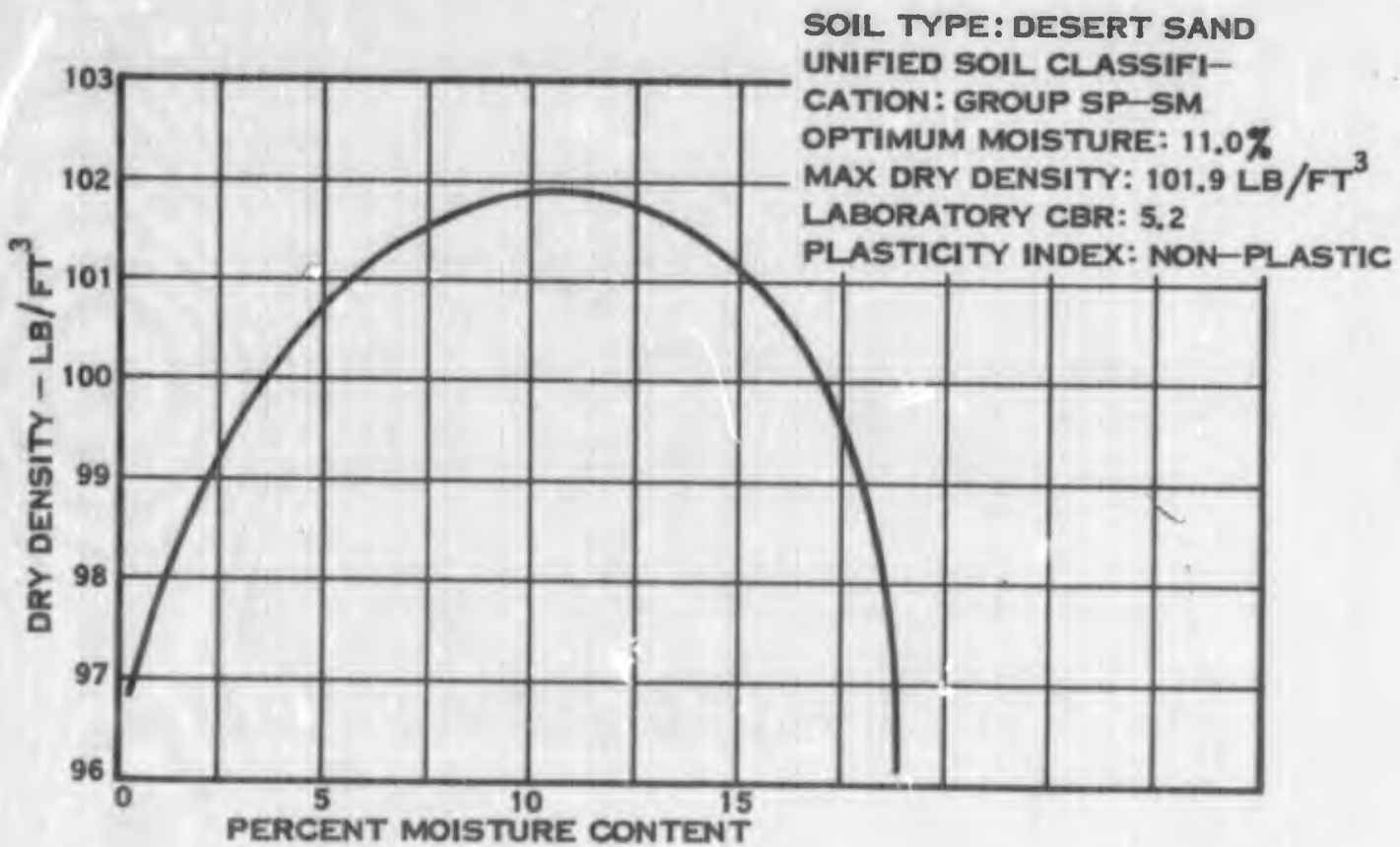


Figure 80. Sieve Analysis and Compaction Test Results for Soil Number 1

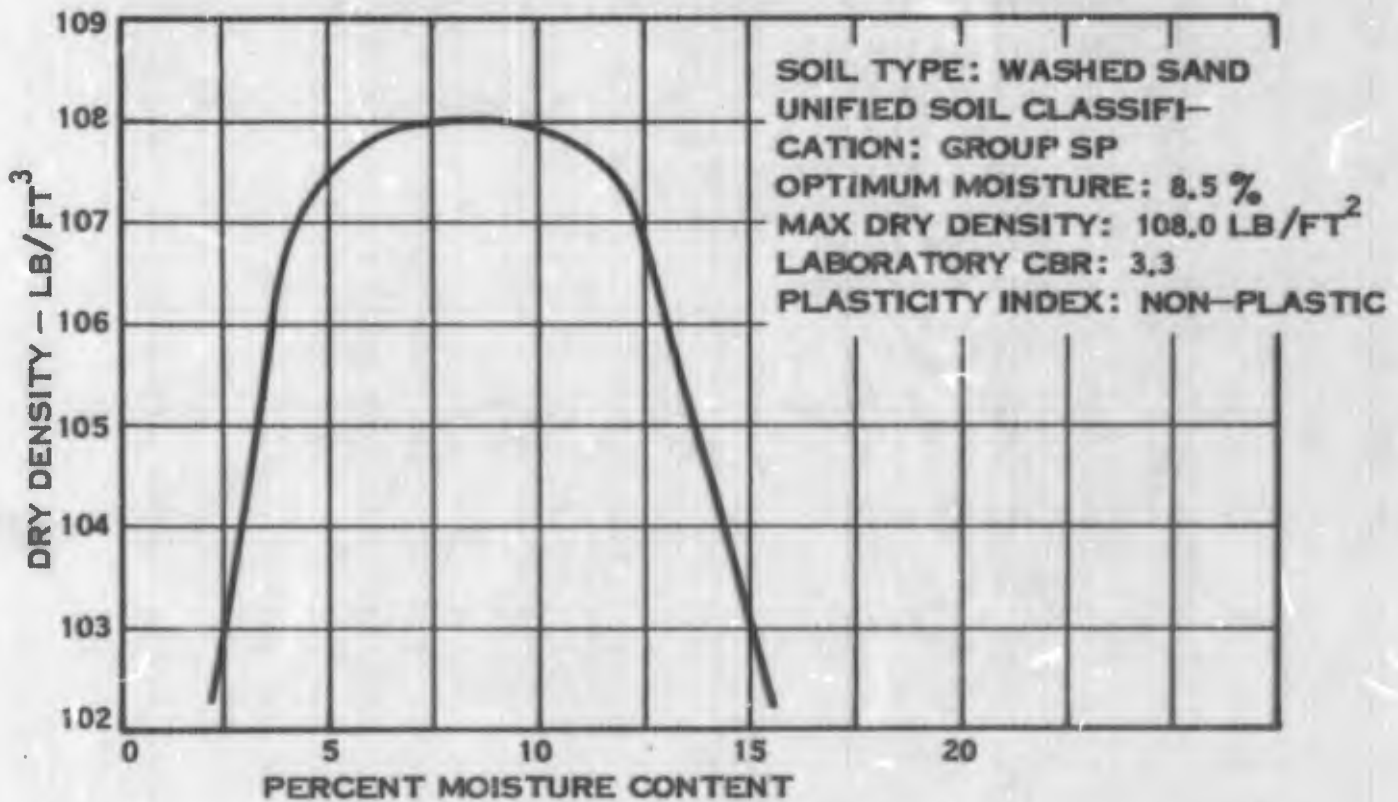
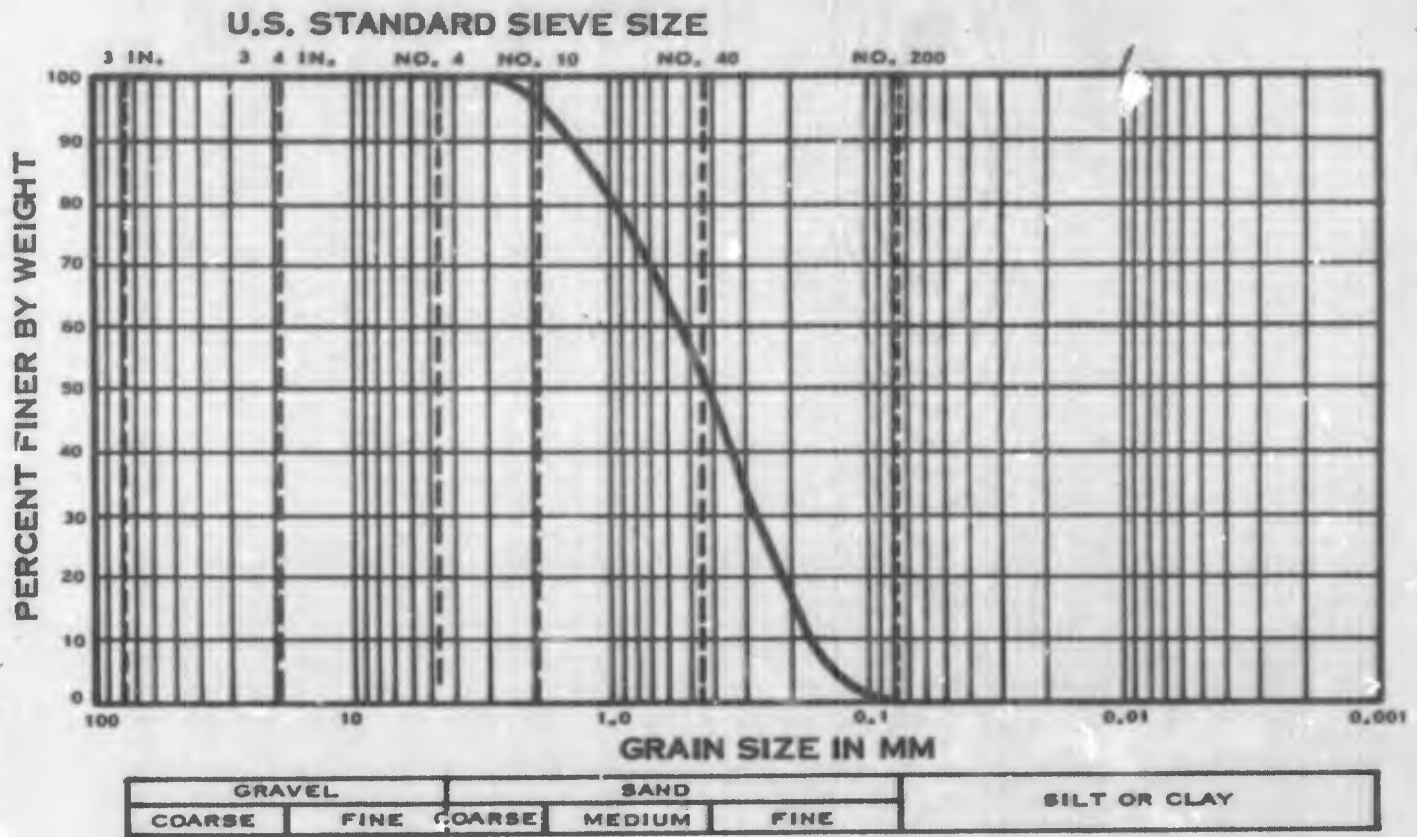
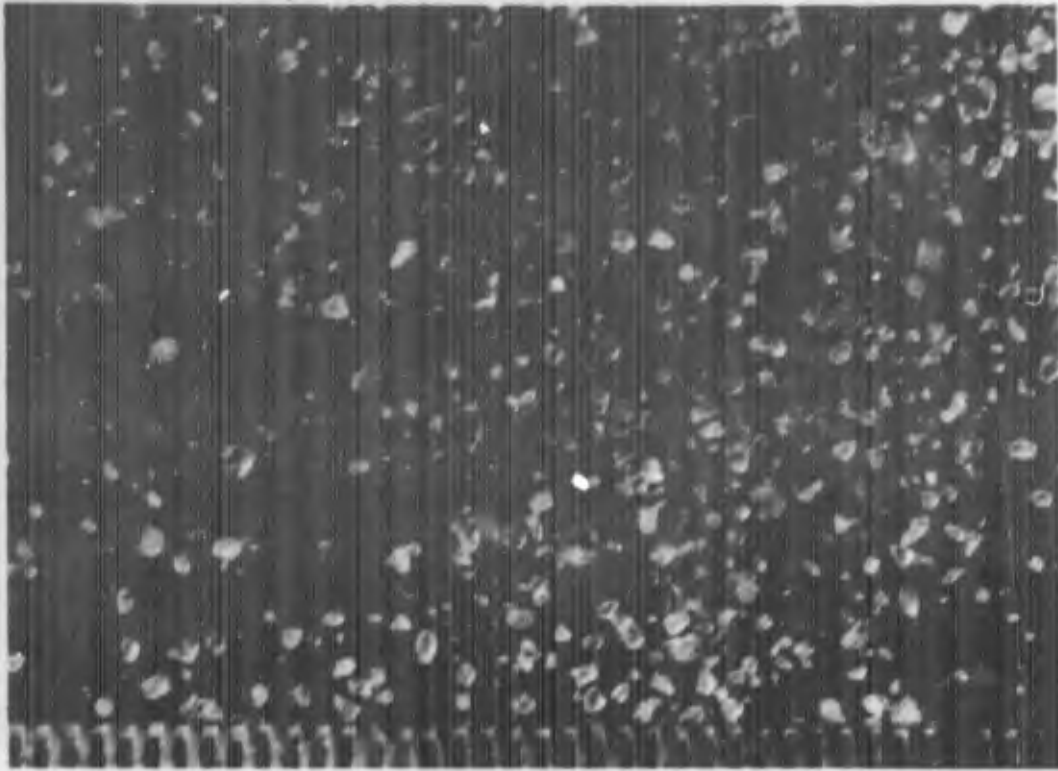
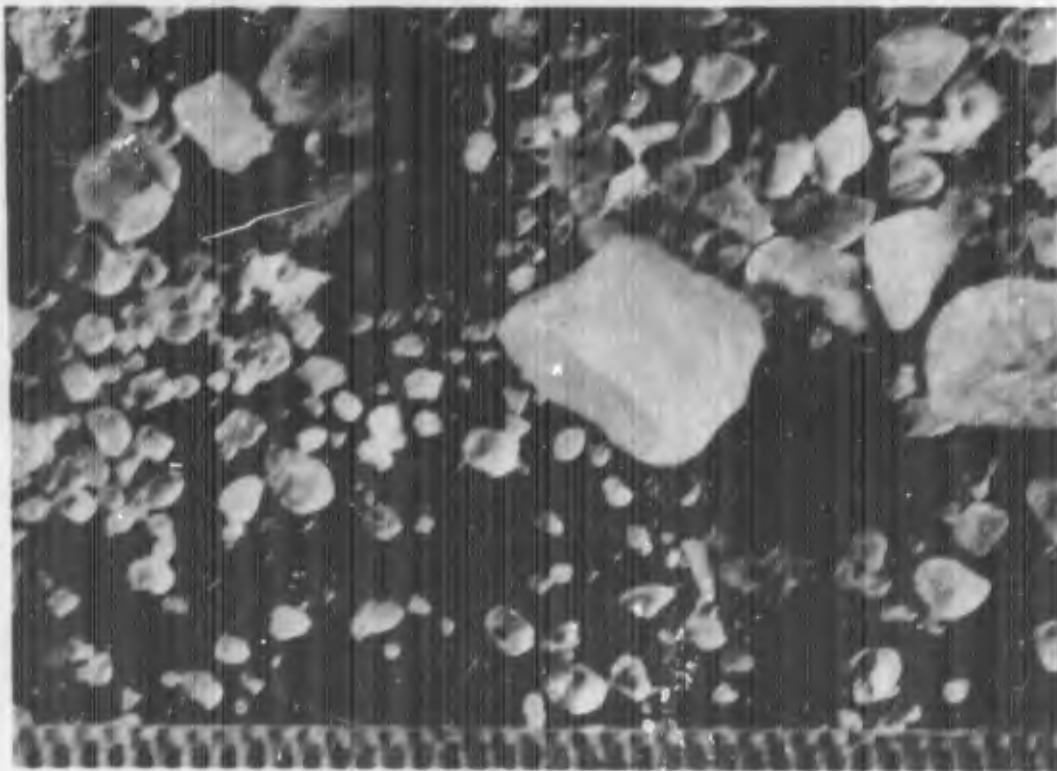


Figure 81. Sieve Analysis and Compaction Test Results for Soil Number 2



SOIL NUMBER 1



SOIL NUMBER 2

Figure 82. Photomicrographs of Soils Number 1 and 2, 10 X Magnification

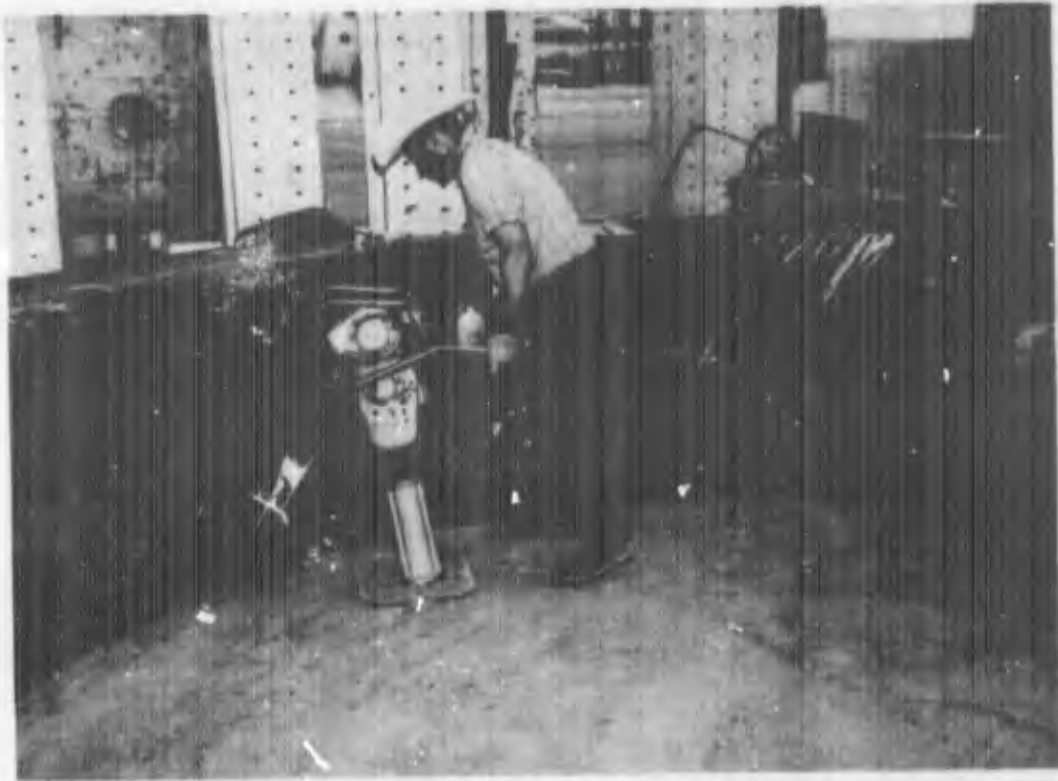


Figure 83. Compaction of Soil Into Retaining Tank



Figure 84. Application of Landing Pad to Soil

The following soil measurements were taken at different intervals during the testing program, to account for changes on the soil conditions.

(1) California Bearing Ratio (CBR)

This test was performed in accordance with the procedures set forth in Reference 5. The CBR test setup is shown in Figure 85.

(2) Moisture content and density.

(3) Cone Penetrometer

A standard Corps of Engineers cone penetrometer was used to measure "cone index" which is an indication of the soil's shearing resistance.

(4) "Ram" Test

A 6.66-inch diameter ram was attached to the load strut and forced into the soil. Ram deflection readings were taken at even load intervals. From this data, the soil modulus and soil deflection characteristic were obtained. The test setup is shown in Figure 86.

Prior to test No. 1, five CBR, moisture content, and density readings were taken. Cone index was measured at this time as well as before each of remaining pad tests. A ram test was also performed. After wheel load test No. 3, the soil properties were rechecked to determine what effect, if any, the possible drying out of the soil might have. Three readings each of CBR, moisture content, and density were made.

The moisture content of the soil was increased prior to test No. 4 in an effort to decrease the CBR value of the soil. This was done by digging up the center portion of the soil (about 6 feet in diameter) and recompacting, while adding water. The soil was soaked with 400 to 500 gallons of water for approximately a 24-hour period. Five readings each of CBR, moisture content, and density were made following the soaking, and preceding test No. 4. Also a ram test was conducted in the same manner as was done previously.

A span of about seven months took place between test No. 4 and No. 1R, which caused a change in the soil properties. Four readings each of CBR, moisture content, and density were taken prior to test No. 1R and again after No. 3R. A ram test was also performed with the soil in this condition.

Prior to test No. 5, Soil No. 1 was removed from the soil box and replaced by Soil No. 2. This soil was prepared in the same manner as before; however, no additional moisture was added. Again, four readings each of CBR, moisture content, and density were taken and the ram test was performed at two locations four feet apart.

Table VII shows a detailed summary of the soil properties for each pad test. Average values of the CBR, moisture content, and density readings are shown in each case. Density is indicated as a percentage of the

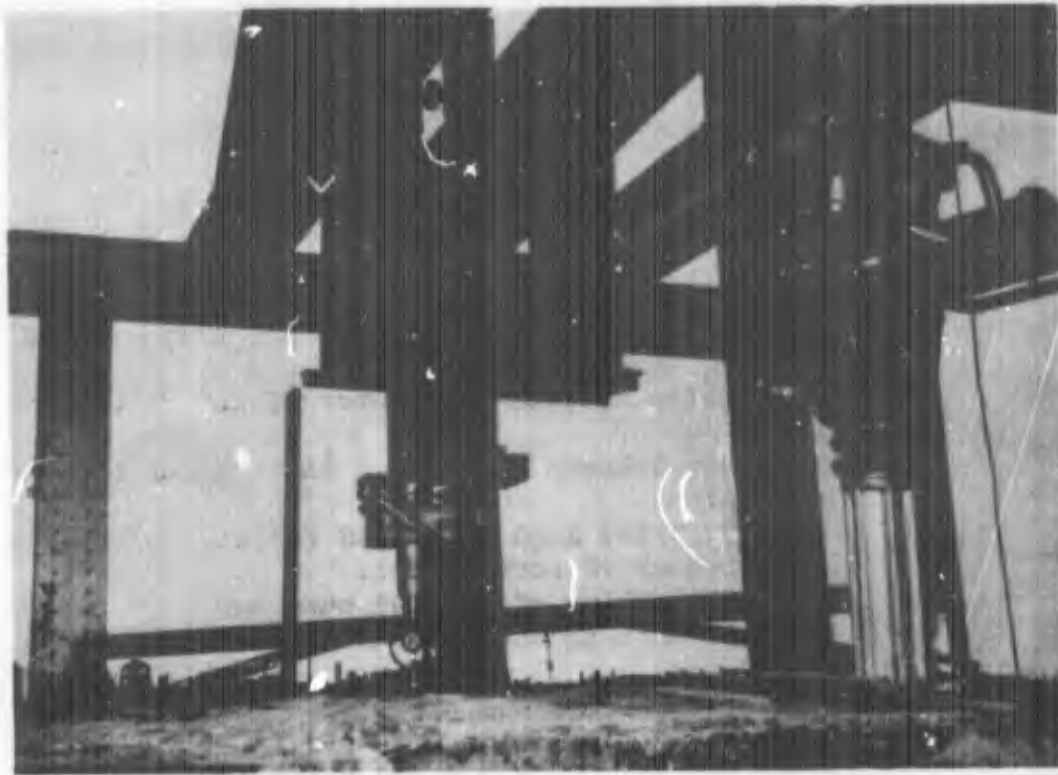


Figure 85. Equipment Required to Obtain CBR Values



Figure 86. Ram Test for Determination of Soil Modulus and Deflection Characteristics

TABLE VII WHEEL LOAD TEST SUMMARY

SOIL DATA						PAD DATA				
TEST NO.	SOIL NO.	CBR (AVG.)	CONE INDEX (AVG.)	MOISTURE CONTENT PERCENT (AVG.)	COMPACTI-ON PERCENT (AVG.)	TYPE <sup>(2)</sup> OF MATERIAL	WEIGHT LB./FT. <sup>2</sup>	PAD <sup>(3)</sup> THICKNESS INCHES (AVG.)	TYPE OF TEST	TIR INFLA PRESS PS
1	1	5.1	10.2	5.6	95.2	A	3.0	.42	Single Wheel	10 20
2	1	6.9 <sup>(1)</sup>	10.5	5.7	95.5	A	4.9	.67	Single Wheel	10 20
3	1	8.6	9.7	5.4	99.1	A	2.3	.36	Dual Wheel	10 20
4	1	4.4	9.6	15.1	97.4	A	3.0	.38	Dual Wheel	10 20
1R	1	7.2	3.5	9.2	92.5	B <sub>2</sub>	2.0	.26	Single Wheel	10 20
2R	1	7.3 <sup>(1)</sup>	6.5	9.2	92.5	B <sub>2</sub>	2.0	.26	Single Wheel	10 20
2 1/2 R-1	1	7.4 <sup>(1)</sup>	2.5	9.2	92.5	B <sub>2</sub>	2.0	.30	Single Wheel	10 20
2 1/2 R-2	1	7.4 <sup>(1)</sup>	9.5	9.2	92.5	B <sub>2</sub>	2.0	.26	Single Wheel	10 20
3R	1	7.5	3.3	9.2	92.5	B <sub>1</sub>	1.3	.14	Single Wheel	10 20
5	2	2.0	<1 <sup>(7)</sup>	3.7	93.4	C <sub>2</sub>	4.0	.59 .58	Single Wheel	10 20
6	2	2.0 <sup>(1)</sup>	1.5	3.7	93.4	B <sub>1</sub>	3.0	.68 .50	Single Wheel	10 20
7	2	2.0 <sup>(1)</sup>	1.4	3.7	93.4	C <sub>1</sub>	3.0	.38 .39	Single Wheel	10 20
8	2	2.0 <sup>(1)</sup>	2.0	3.7	93.4	B <sub>1</sub>	3.0	.53 .41	Single Wheel	10 20

A

WHEEL LOAD DATA				
TIRE (8) INFLATION PRESSURE PSI	MAXIMUM TOTAL LOAD LB.	FAILURE?		MAXIMUM PAD DEFLECT. INCHES
		YES	NO	
100	15,000		X	-
200	12,000	X		1.7
100	15,000		X	-
200	19,000	X		1.9
100	30,000		X	-
200	45,000	X		1.2(5)
100	30,000(4)	X		1.4(5)
200	-			-
100	15,000		X	.50
200	22,000		X	.75
100	15,000		X	.62
200	22,000		X	.97
100	15,000		X	1.22
200	22,000		X	1.36
100	15,000		X	.34
200	22,000		X	.49
100	15,000		X	2.45(6)
200	22,000		X	4.70 (6)
100	15,600		X	1.00
200	22,000		X	1.38
100	15,000		X	1.45
200	22,000		X	2.02
100	15,000		X	1.02
200	22,000		X	1.70
100	15,000		X	.50
200	22,000		X	1.16

**NOTES:**

- (1) CBR was not taken. The values are proportioned from the measured readings.
- (2) Subscripts indicate the number of layers of woven roving.
- (3) Average thickness within 2.5 feet radius of wheel centerline.
- (4) Soil supported load after pad failed.
- (5) Under center of north wheel.
- (6) Severe wrinkling of the pad occurred.
- (7) Soil too soft to obtain reading.
- (8) Tire Data:  
 Test tires: 26 x 6.6, 16 ply, 300 psi standard inflation pressure  
 P.1127 tires: 26 x 6.5, 14 ply, 105 psi standard inflation pressure  
 VJ101C-X2 tires: 25.5 x 6.5, (N.A. ply), 206 psi standard inflation pressure

**PAD MATERIALS**

A---Formula B-3-B (contract AF 33(615)-2367)

B---Resin: Hetrion 75/25--31/42 (24505)  
 with 0.5% Co. Naphth. and 0.05% DMA  
 Glass reinforcement: PFG 533-60 spray roving and woven roving\*

**C---Composite System**

**First Layer**

Resin: Hetrion 75/25--31/42 (24505)  
 with 0.5% Co. Naphth. and 0.05% DMA  
 Glass reinforcement: PFG 533-60 spray roving and woven roving\*

**Second Layer**

Resin: 66% Hetrion 75/25--353/42,  
 30% H<sub>2</sub>BO<sub>3</sub>, 3% Sb<sub>2</sub>O<sub>3</sub>, and 1% CAB-O-SIL M-5  
 Glass reinforcement: PFG 533-60  
 spray roving\*

D---Resin: Laminac 75/25--176/126; Glass reinforcement:  
 PFG 533-60 spray roving and woven roving\*

\* Each pad contains 3-5% spray roving except for pad #8 which contains about 10%.

B

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maximum density obtained from the laboratory compaction test of each soil. Cone index values are shown as the average of several readings. Figures 87 and 88 show the results of the ram tests performed on Soil No. 1 and Figures 89 and 90 that on Soil No. 2.

Wheel load tests without a pad were performed on Soil No. 1 before pad test No. 1R and on Soil No. 2 before pad test No. 5. This was done using single tires at both 100-psi and 200-psi tire inflation pressures for each soil. Figure 91 shows the 200-psi tire on Soil No. 1 under a load of 12,600 pounds and Figure 92 the 100-psi tire on Soil No. 2 at 7,600 pounds. The load vs soil deflection curves for these tests are shown in Figures 93 and 94.

All the pads were tested at 100- and 200-psi tire inflation pressures, each using the single wheel except pads No. 3 and No. 4 which used the dual wheel configuration. For each test, the load was increased in specified increments until the pad failed or the tire load limit was reached. Pads No. 3 and No. 4 were each instrumented with four strain gages and pads No. 1R and No. 7 with 6 gages to indicate the upper surface stresses on the pads. Strain readings were taken at specific load increments.

For pad tests No. 1 through No. 3R, the pad was loaded with the 100-psi tire and then immediately with the 200-psi tire. For pad tests No. 5 through No. 8, the completion of additional load struts made it possible to load the 100-psi tire at one point on the pad, and the 200-psi tire at another.

Tire contact area measurements were made at various load levels during pad tests No. 1 through No. 4. These measurements were difficult to make and their accuracy was questionable since there was a lot of scatter. Therefore, the tires were calibrated in the laboratory on a universal test machine. They were loaded against a steel plate and the tire footprints were measured at 2000-pound increments of load. The tire was coated with ink and an imprint was made on a sheet of paper placed between the tire and the steel plate. Figure 95 shows a plot of wheel load vs tire contact area for each tire. Both of the tires that were tested showed close agreement, so these curves will be used to indicate the tire contact area at any load level.

After each pad was removed from the soil, it was cut into four 90-degree segments (or quadrants). Thickness measurements were made at six-inch intervals along the cut edges of the pads. Table VIII gives a thickness survey of each pad over a 2-1/2-foot radius from the center of the load. A summary of the pad data for each test, including the type of material, weight, and average thickness is shown in Table VII.

Four tensile and four bending specimens were cut from each of the test pads. For pads No. 1R through No. 8, specimens were cut both in the direction of the woven roving fibers and at an angle of 45°. The specimens were tested to failure to determine the allowable tensile and bending stresses and modulus of the pad material. The results of these tests are shown in Table IX. Similar specimens were cut from the remote

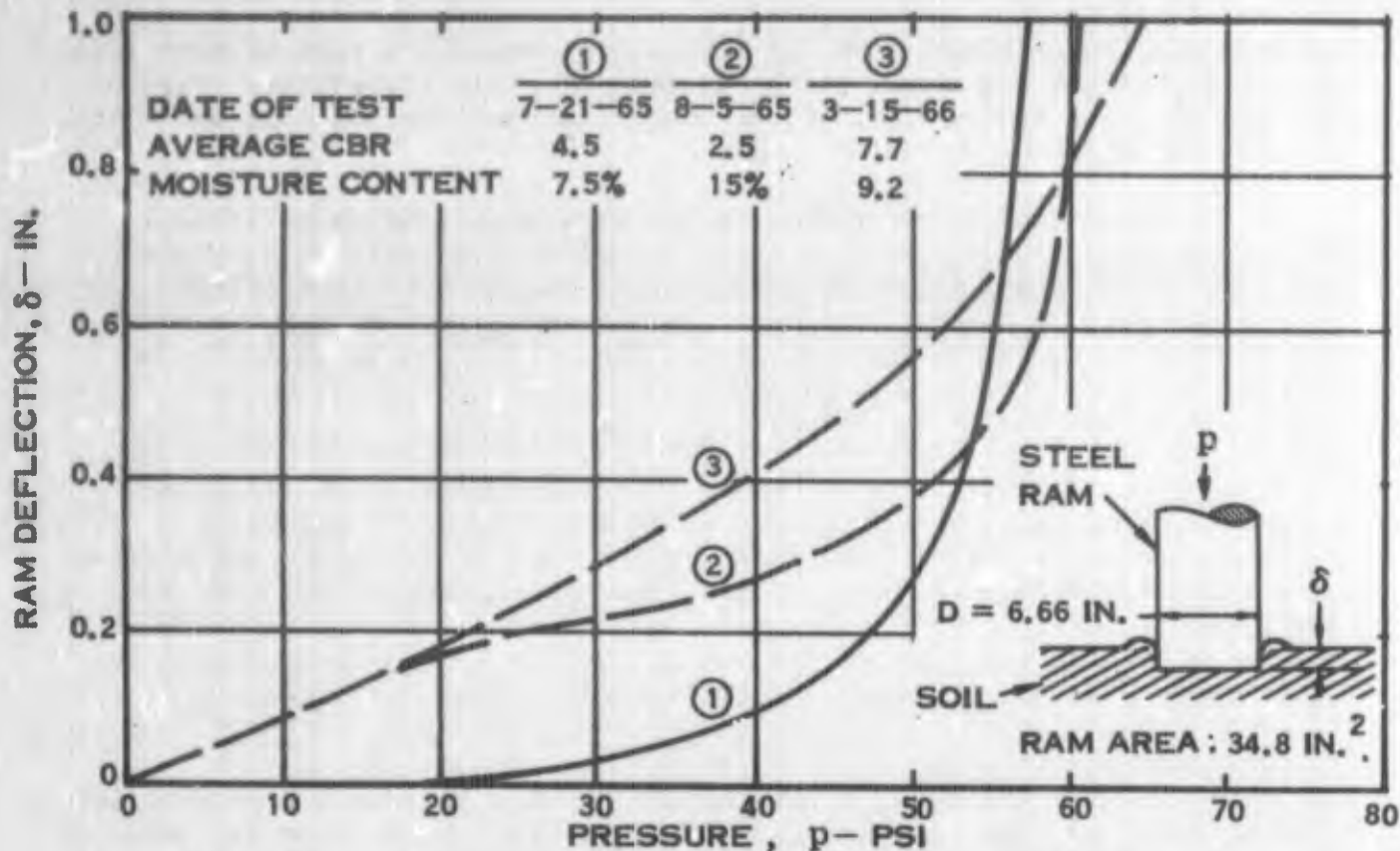


Figure 87. Deflection vs Pressure, Ram Test on Soil Number 1

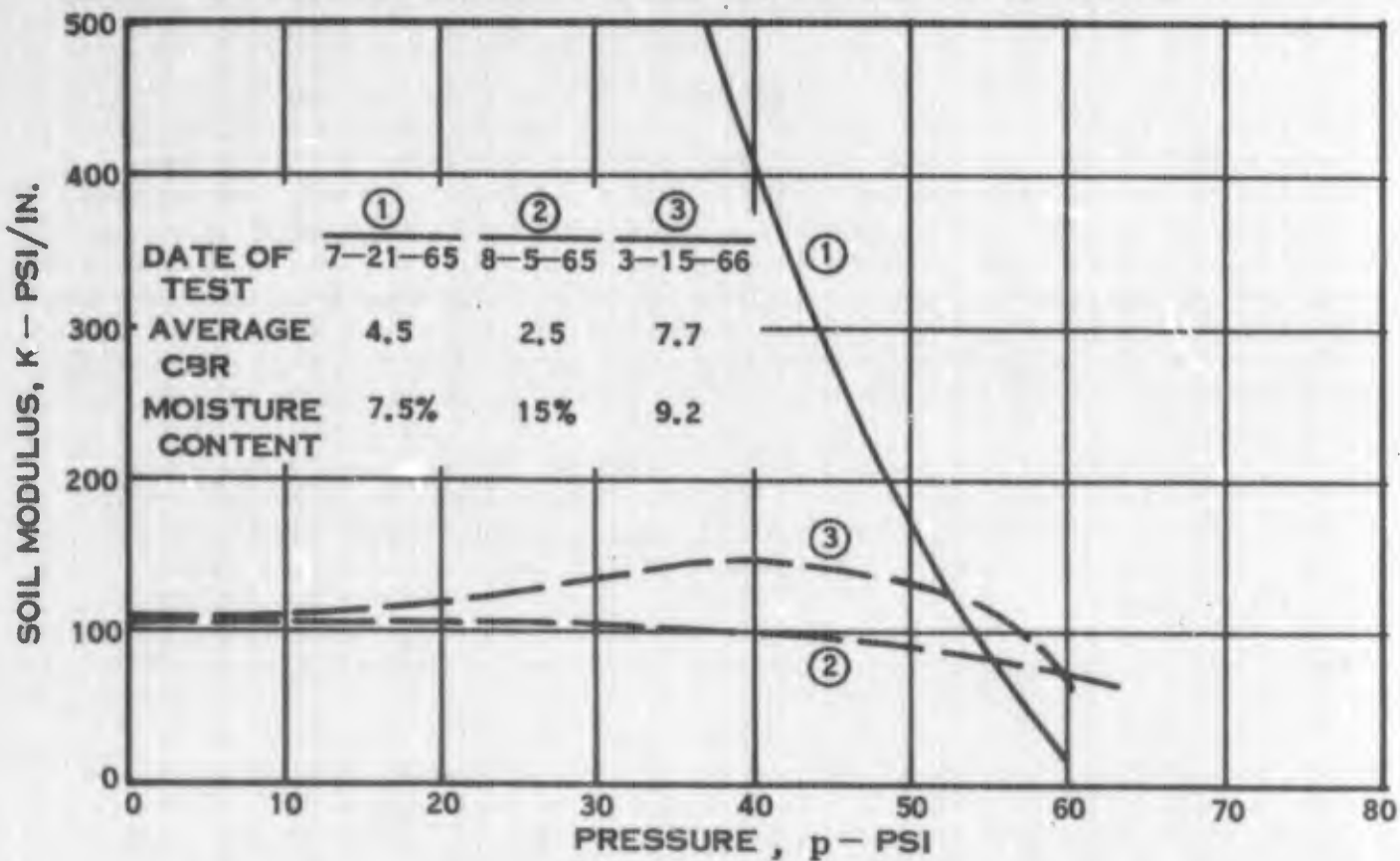


Figure 88. Soil Modulus vs Pressure, Ram Test on Soil Number 1

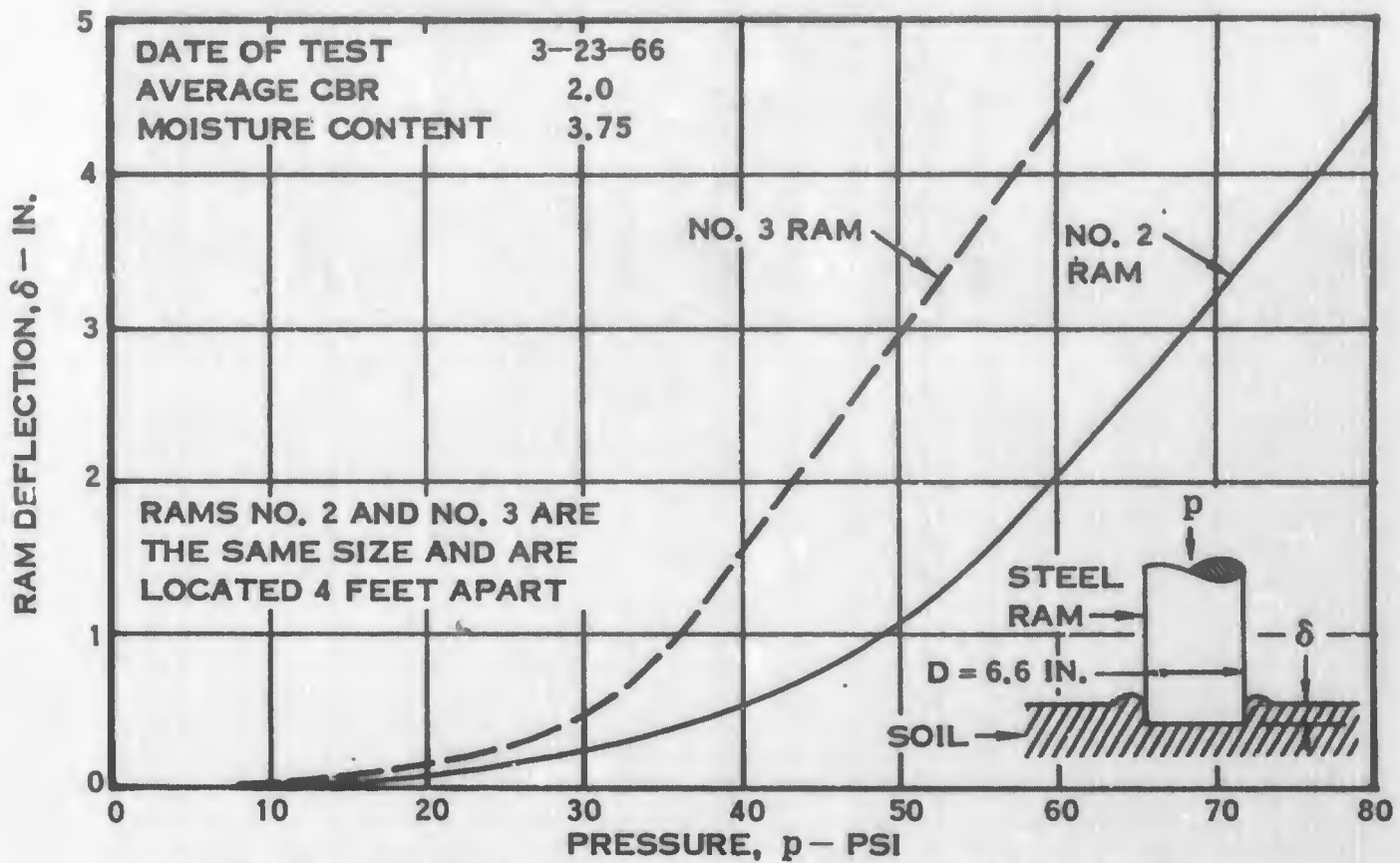


Figure 89. Deflection vs Pressure, Ram Test on Soil Number 2

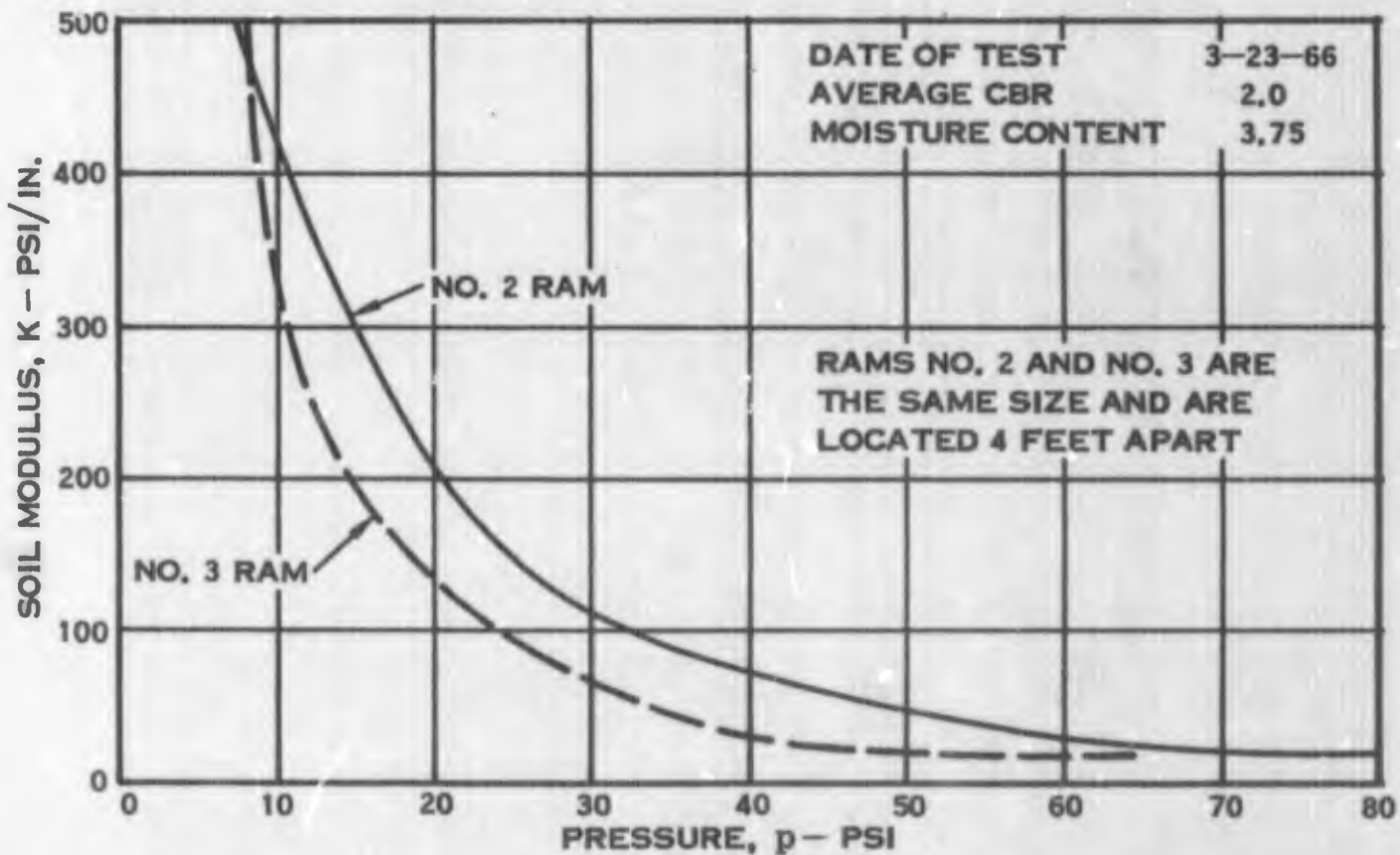


Figure 90. Soil Modulus vs Pressure, Ram Test on Soil Number 2



Figure 91. 200-psi Tire on Soil Number 1 at 12,600 Pounds



Figure 92. 100-psi Tire on Soil Number 2 at 7,600 Pounds

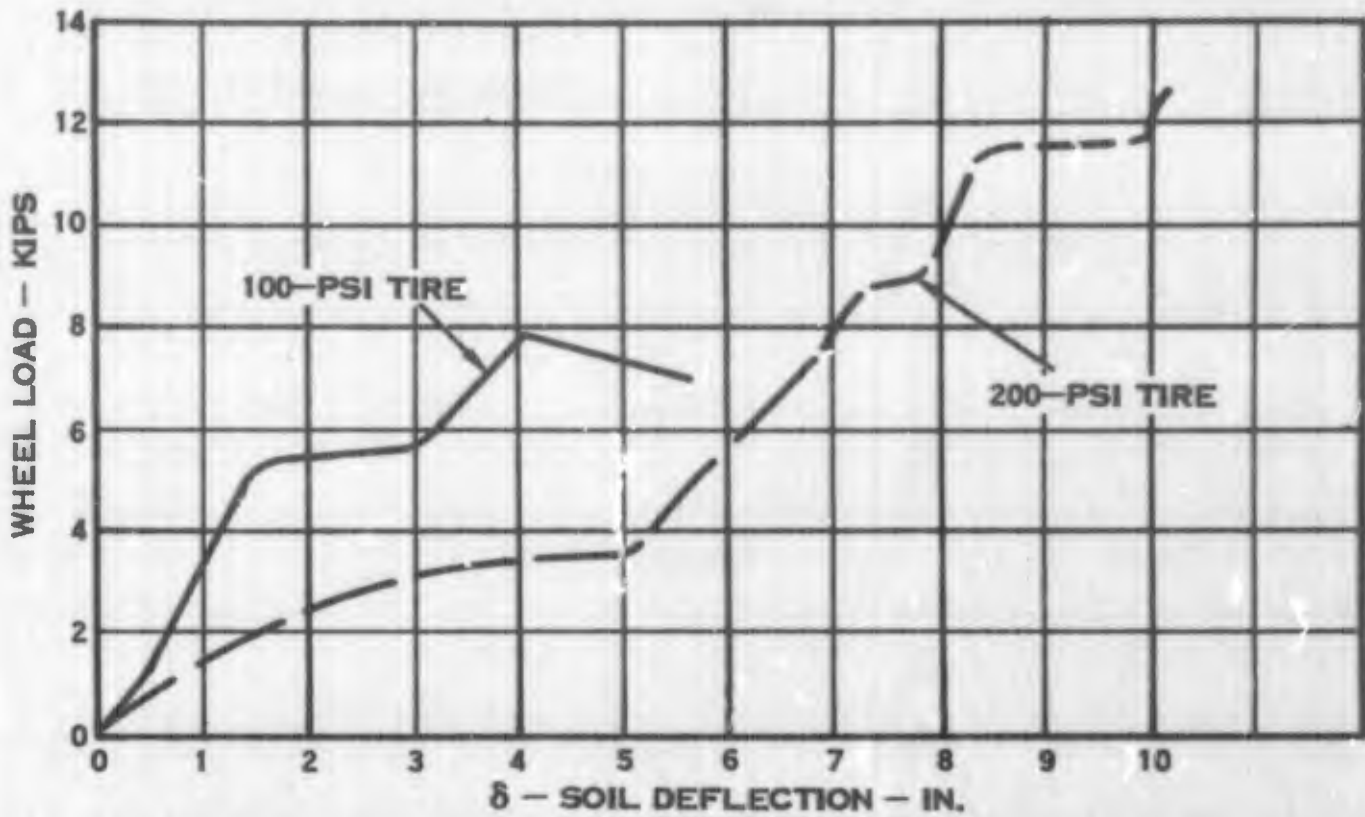


Figure 93. Load vs Deflection for Wheel Load Test Without Pad, Soil Number 1

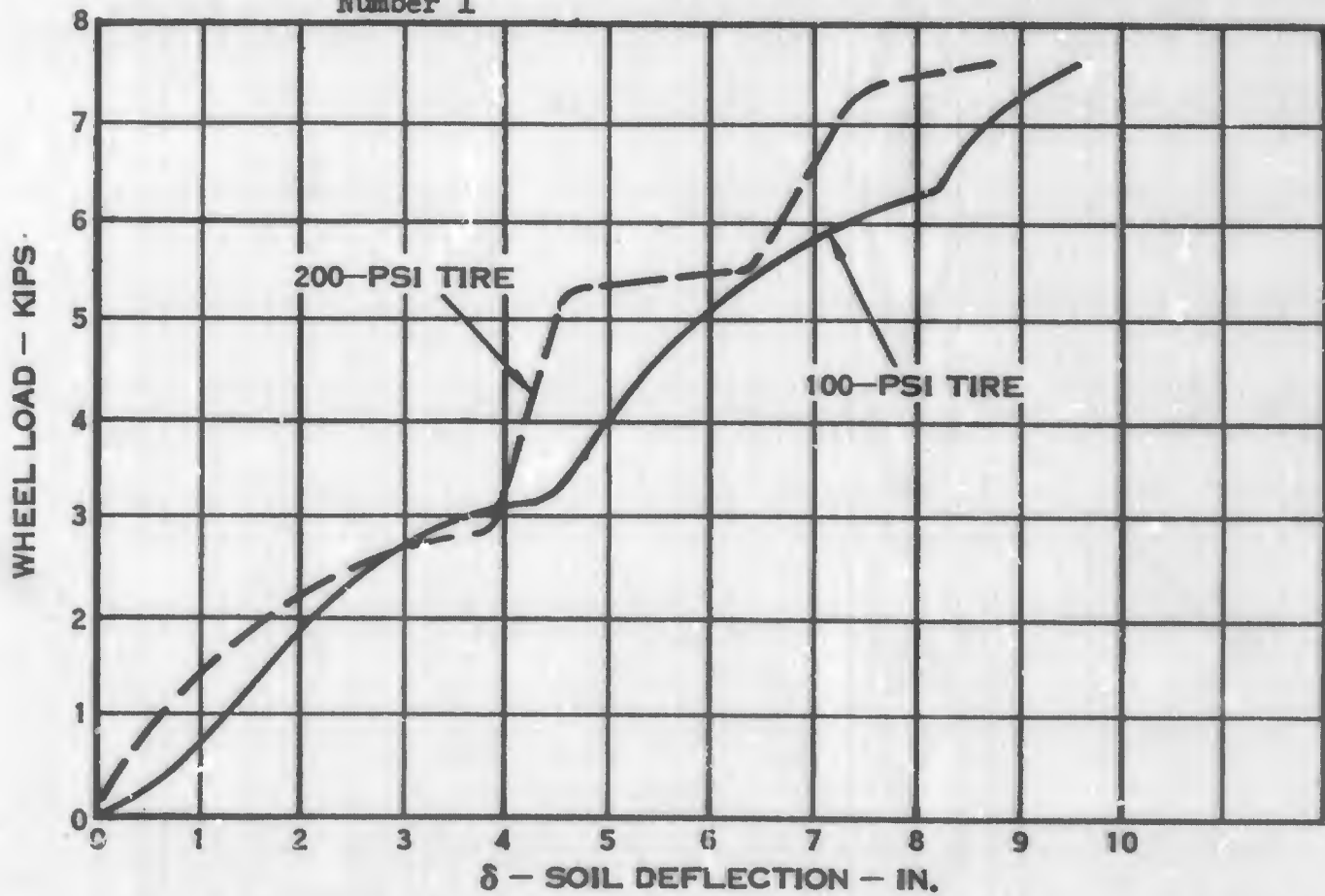


Figure 94. Load vs Deflection for Wheel Load Test Without Pad, Soil Number 2

- ① GOODYEAR 26X6.6 TYPE VII
- ② U.S. ROYAL 26X6.6 TYPE VII

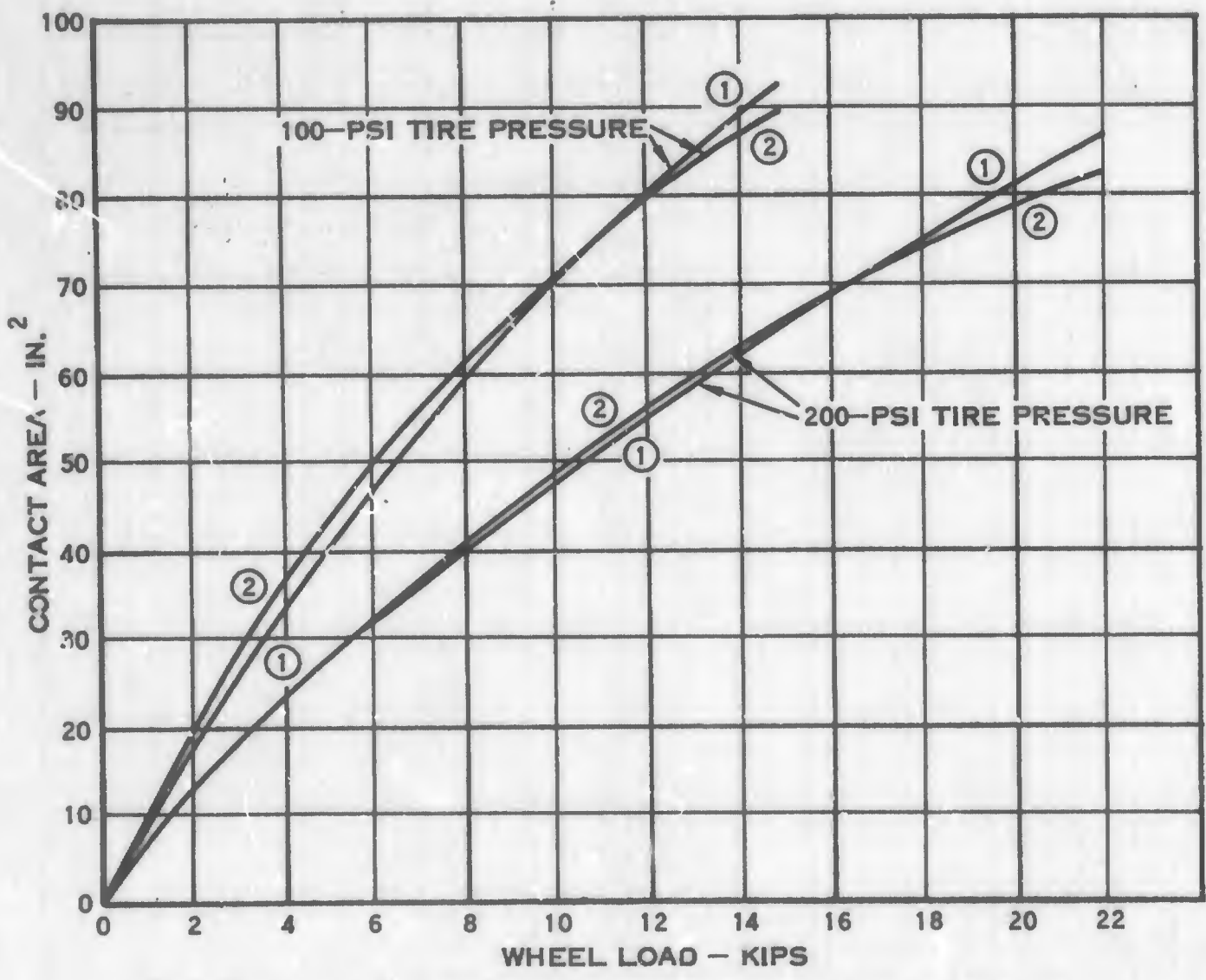
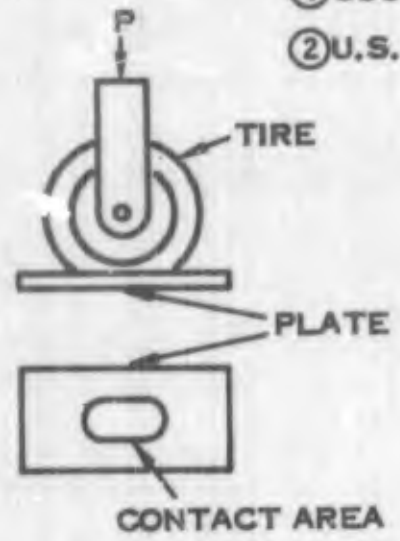


Figure 95. Tire Contact Area vs Wheel Load, Tire Calibration

TABLE VIII PAD THICKNESS

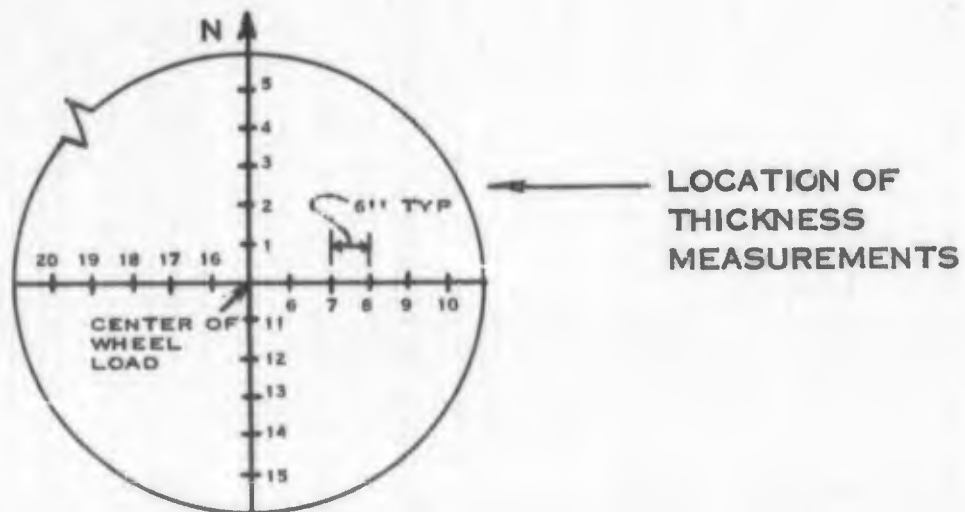
THICKNESS LOCATION	PAD NUMBER (THICKNESS)							
	1	2	3	4	1R	2R	2 1/2R-1	2 1/2R-2
1	.39	.62	.26	.45	.30	.25	.22	.45
2	.47	.66	.28	.43	.37	.22	.30	.35
3	.43	.70	.30	.52	.35	.25	.21	.15
4	.41	.71	.37	.56	.20	.27	.50	.28
5	.47	.66	.33	.49	.50	.27	.38	.27
6	.45	.59	.33	.38	.21	.18	.32	.21
7	.35	.58	.35	.25	.26	.24	.25	.40
8	.36	.61	.38	.21	.15	.18	.18	.20
9	.29	.64	.45	.24	.18	.17	.30	.17
10	.53	.64	.36	.23	.10	.17	.35	.44
11	.47	.58	.28	.37	.33	.25	.23	.18
12	.37	.58	.37	.37	.20	.35	.36	.38
13	.51	.54	.37	.37	.20	.20	.28	.20
14	.56	.56	.50	.45	.19	.50	.27	.20
15	.52	.60	.55	.33	.18	.45	.20	.18
16	.39	.81	.29	.63	.30	.27	.25	.29
17	.39	.88	.34	.44	.26	.26	.23	.23
18	.41	.87	.33	.25	.30	.36	.40	.25
19	.30	.83	.30	.32	.27	.22	.50	.27
20	.24	.72	.39	.30	.25	.16	.24	.20
AVERAGE THICKNESS	.42	.67	.36	.38	.26	.26	.30	.26

## NOTES:

- (1) PORTION OF PAD USED FOR THE 100-PSI TEST ONLY.
- (2) PORTION OF PAD USED FOR THE 200-PSI TEST ONLY.

PAD THICKNESS SURVEY

NUMBER (THICKNESS IS IN INCHES)									
2R-2	3R	5(1)	5(2)	6(1)	6(2)	7(1)	7(2)	8(1)	8(2)
.45	.12	.51	.70	.60	.30	.40	.40	.45	.40
.35	.05	.65	.55	.75	.50	.33	.45	.45	.48
.15	.05	.92	.60	.75	.20	.35	.42	.40	.40
.28	.03	.50	.67	.90	.60	.35	.35	.40	.48
.27	.10	.40	.50	.95	.50	.45	.40	.40	.50
.21	.12	.50	.58	.65	.17	.35	.45	.55	.50
.40	.10	.62	.60	.75	.30	.40	.43	.50	.35
.20	.25	.54	.70	.60	.17	.30	.40	.65	.30
.17	.10	.70	.70	.70	.65	.30	.43	.50	.38
.44	.20	.80	.58	.60	.25	.38	.25	.45	.30
.18	.10	.50	.65	.70	.70	.45	.45	.65	.40
.38	.15	.60	.50	.70	.65	.45	.40	.70	.50
.20	.10	.55	.62	.60	.85	.45	.35	.80	.45
.20	.10	.40	.45	.65	.65	.33	.35	.65	.35
.18	.10	.45	.30	.70	.80	.28	.40	.65	.35
.29	.12	.65	.60	.60	.60	.40	.40	.60	.45
.23	.35	.45	.60	.65	.50	.50	.35	.45	.50
.25	.45	.68	.65	.55	.55	.45	.40	.45	.50
.27	.05	.66	.65	.50	.50	.40	.35	.45	.46
.20	.10	.70	.45	.75	.60	.35	.45	.45	.25
.26	.14	.59	.58	.68	.50	.38	.39	.53	.41



B

TABLE IX PAD MATERIAL ELEMENT SPECIMEN TESTS

Pad No.	Type(1) of Material	TENSILE SPECIMEN TESTS				BENDING SPECIMEN TESTS				Pad No.
		Spec. No.	Thickness In.	F <sub>tu</sub> PSI	E PSI x 10 <sup>6</sup>	Spec. No.	Thickness In.	F <sub>bu</sub> PSI	E <sub>b</sub> (2) PSI x 10 <sup>6</sup>	
1	A	1	.44	1,050	.66	1	.31	3,130	.84	3R
		2	.36	1,050	.98	2	.29	4,550	.69	
		3	.29	1,420	.78	3	.24	3,970	.69(84)	
		4	-	--	-	4	.24	5,970	.75	
		AVG.		1,170	.81	AVG.		4,400	.74	
2	A	1	.28	910	.77	1	.37	4,030	.81(.73)	5
		2	.46	980	.72	2	.45	3,810	.67	
		3	.50	2,210	1.00	3	.42	2,870	.63	
		4	.54	1,580	.86	4	.59	3,500	.66	
		AVG.		1,420	.84	AVG.		3,550	.69	
3	A	1	.30	1,740	.81	1	.17	4,410	.67	6
		2	.30	2,060	.91	2	.20	4,820	.83	
		3	.40	1,750	.81	3	.25	4,400	.57(83)	
		4	.51	1,500	.80	4	.15	5,090	.69	
		AVG.		1,760	.83	AVG.		4,680	.69	
4	A	1	.18	1,890	.87	1	.20	4,540	.68	7
		2	.19	1,100	.55	2	.20	5,220	.73	
		3	.20	1,750	.80	3	.25	4,450	.69(83)	
		4	.12	2,040	.96	4	.17	4,320	.91	
		AVG.		1,700	.80	AVG.		4,630	.80	
1R	B <sub>2</sub>	1 (3)	.21	5,550	-	1 (3)	.19	13,700	.52	8
		2	.20	10,400	.41	2	.19 (4)	13,300	.59	
		3	.22	9,420	.57	3	.32	18,100	.39	
		4 (3)	.34	3,390	-	4 (3)	.24	10,200	.29	
		AVG.		7,190	.49	AVG.		13,620	.45	
2R	B <sub>2</sub>	1 (3)	.22	6,790	.33	1 (3)	.24 (4)	9,500	.37	English Site
		2	.25	11,000	-	2	.22	7,300	.55	
		3	.20	10,700	-	3	.20 (4)	15,200	.63	
		4 (3)	.23	5,100	.20	4 (3)	.21 (4)	14,900	.66	
		AVG.		8,400	.27	AVG.		11,720	.55	
2 1/2 R-1	B <sub>2</sub>	1	.24	11,600	-	1	.28	26,400	1.4	German Site
		2 (3)	.37	7,230	-	2 (3)	.38	7,800	.40	
		3 (3)	.31	4,950	-	3 (3)	.27	12,000	.44	
		4	.26	10,000	-	4	.22	15,200	.53	
		AVG.		8,450	-	AVG.		15,350	.71	
2 1/2 R-2	B <sub>2</sub>	1	.31	8,950	.65	1	.32	20,200	.66	NOT
		2 (3)	.19	4,820	.30	2 (3)	.20 (4)	11,200	.53	
		3	.23	11,400	-	3	.19	13,700	.79	
		4 (3)	.18	8,760	.48	4 (3)	.21	7,500	.35	
		AVG.		8,440	.48	AVG.		13,150	.58	

(1)  
(2)  
(3)  
  
(4)

A

TENSILE SPECIMEN TESTS				BENDING SPECIMEN TESTS			
Spec. No.	Thickness In.	F <sub>0.2</sub> PSI	E PSI x 10 <sup>6</sup>	Spec. No.	Thickness In.	F <sub>0.2</sub> PSI	E <sub>0</sub> PSI x 10 <sup>6</sup>
1	.16	7630	-	1	.11	9200	.72
2	.15	9370	.45	2	.14	5670	.53
3 (3)	.15	3810	-	3 (3)	.14	5000	.21
4	.18	12,300	-	4	.16	9700	.57
AVG.		8260	.45	AVG.		7390	.51
1	.53	3,150	.67	1	.54	13,800	.53
2	.62	3,990	.67	2	.54	3,400	.55
3 (3)	.59	4,360	.53	3 (3)	.51	16,600	.50
4 (3)	.68	2,870	.72	4 (3)	.58	3,300	.50
AVG.		3,590	.70	AVG.		9,770	.52
1 (3)	.11	4,500	-	1	-	-	-
2	.13	4,940	-	2	-	-	-
3	.14	6,500	.58	3	-	-	-
4 (3)	.14	7,500	-	4	-	-	-
AVG.		5,000	.58	AVG.		-	-
1 (3)	.32	4,470	.90	1 (3)	.35	8,400	.61
2	.44	2,960	-	2	.42	21,800	1.08
3 (3)	.38	4,830	.28	3 (3)	.40	19,600	.61
4	.28	6,480	.01	4	.26	8,600	.83
AVG.		4,680	.06	AVG.		14,600	.78
1	.30	7,840	.67	1	.38	17,900	.57
2 (3)	.29	4,890	.45	2 (3)	.25	10,700	.56
3	.69	3,860	.35	3	.48	14,300	.99
4 (3)	.43	4,740	.39	4 (3)	.40	24,600	.37
AVG.		5,280	.46	AVG.		18,870	.62
1	.35	1,430	.69	1	.46	4,010	.69
2	.43	2,240	.74	2	.67	4,330	.56
AVG.		1,830	.71	AVG.		4,170	.62
1	.34	1,505	.73	1	.68	3,230	.21
2	.58	1,330	.64	2	.51	7,360	.61
AVG.		1,420	.68	AVG.		5,290	.41

Description of the pad materials is given in Table 4.1.1. Modulus (E<sub>0</sub>) values shown in parentheses, ( ), are strain gage values. Specimens were cut so that the principal stress direction is oriented at 90 degrees with respect to the woven roving fibers. The remaining specimens are oriented parallel to the fibers. Specimen did not rupture. The test was stopped when the deflection reached 0.5 inches over a span of 6.0 inches.

B

pads that were fabricated in England and Germany. A description of these remote sites is given in Section V of this report. Their material properties are also shown in Table VII.

c. Discussion of Wheel Load Tests and Summary of Results

Pad No. 1 - No failure occurred with the 100-psi tire; however, a visual inspection revealed a small resin crack approximately six inches long, along the edge of the tire mark on the pad. Figure 96 shows the 100-psi tire at a load of 15,000 pounds. When the 200-psi tire reached a load of 8,000 pounds, the pad cracked completely around the tire. The load was gradually increased to 12,000 pounds at which time the pad area beneath the tire failed in shear. This failure is shown in Figure 97. Figure 98 shows the deflected shape of the soil after removal of the failed pad.

Pad No. 2 - The 100-psi tire produced no failures nor were any cracks noticeable. The 200-psi test produced excessive cracking noises as the load reached 18,000 pounds. Failure of the pad occurred at 19,000 pounds and is shown in Figure 99.

Pad No. 3 - The 100-psi tire produced no failures nor were any cracks noticeable. Figure 100 shows the wheels and pad with a total applied load of 30,000 pounds (15,000 pounds on each tire). The 200-psi tire test produced a pad failure at a load of 45,000 pounds. Figure 101 shows this pad failure. The location of the strain gages and normal pad stress vs wheel load are shown in Figure 102. The results were reduced from the strain gage readings for both the 100-psi and 200-psi tire inflation pressures.

Pad No. 4 - For the 100-psi test, slight cracking noises were heard at 11,000 pounds and again at 26,000 pounds. There was no indication of failure to the pad when the 30,000-pound load was applied but, after holding this load for seven minutes, the pad failed. This failure is shown in Figure 103. The 200-psi test was not performed due to the pad failure. Figure 104 shows the results obtained from the strain data.

In each of the above tests, the deflections were not accurately determined at various load levels. However, the maximum deflections were obtained and are summarized in Table VII.

Pad No. 1R through 8 - None of the pads in this series of tests failed by rupturing nor were any cracks apparent. Each of these pads used woven roving and were treated with a flexible resin. This was not the case for the first four pads. Deflection measurements were made at various load increments because it was necessary to establish the limits of the pad deformation. Load vs deflection and tire contact pressure vs deflection curves for each of these pad tests are shown in Figures 105 through 113. Figures 114 and 115 show the strain gage locations and nominal pad stress vs wheel load for pad tests No. 1R and No. 7, respectively. Pad No. 3R buckled severely and had excessive deflection. This can be seen in Figures 116 and 117. Except for pad No. 3R, the others deformed in much the same manner. Some typical cases are shown in Figures 118 through 121.

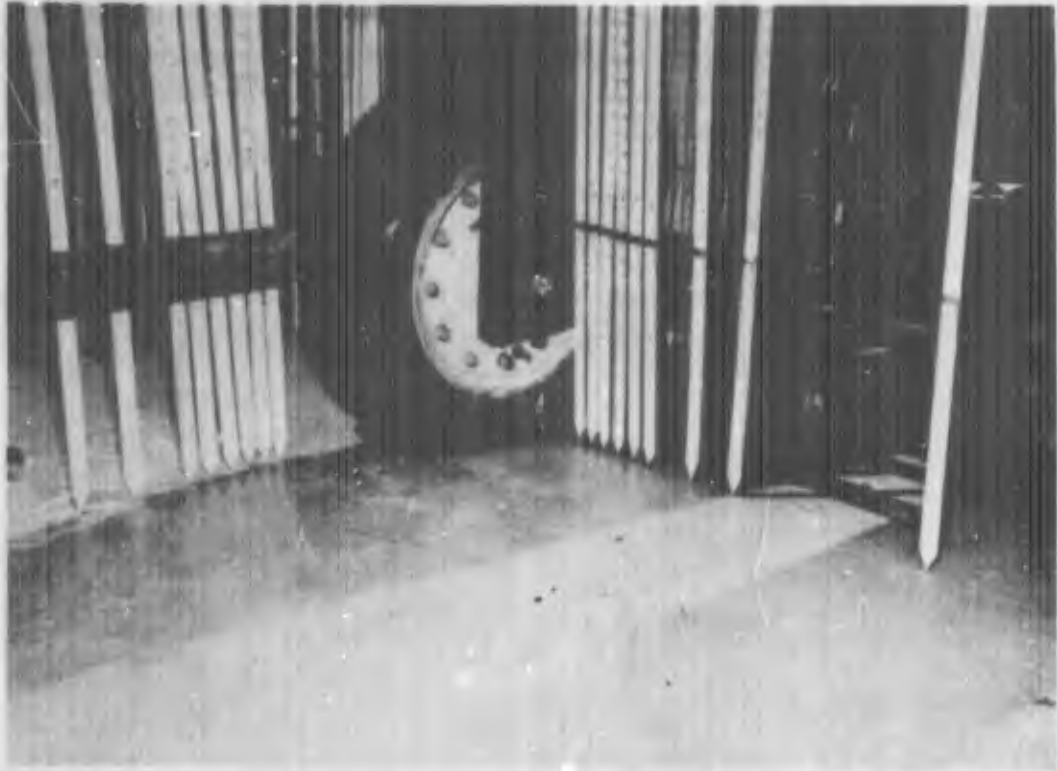


Figure 96. Test Number 1 - 15,000-lb Load Applied, 100-psi Tire Inflation Pressure



Figure 97. Test Number 1 - After Pad Failure

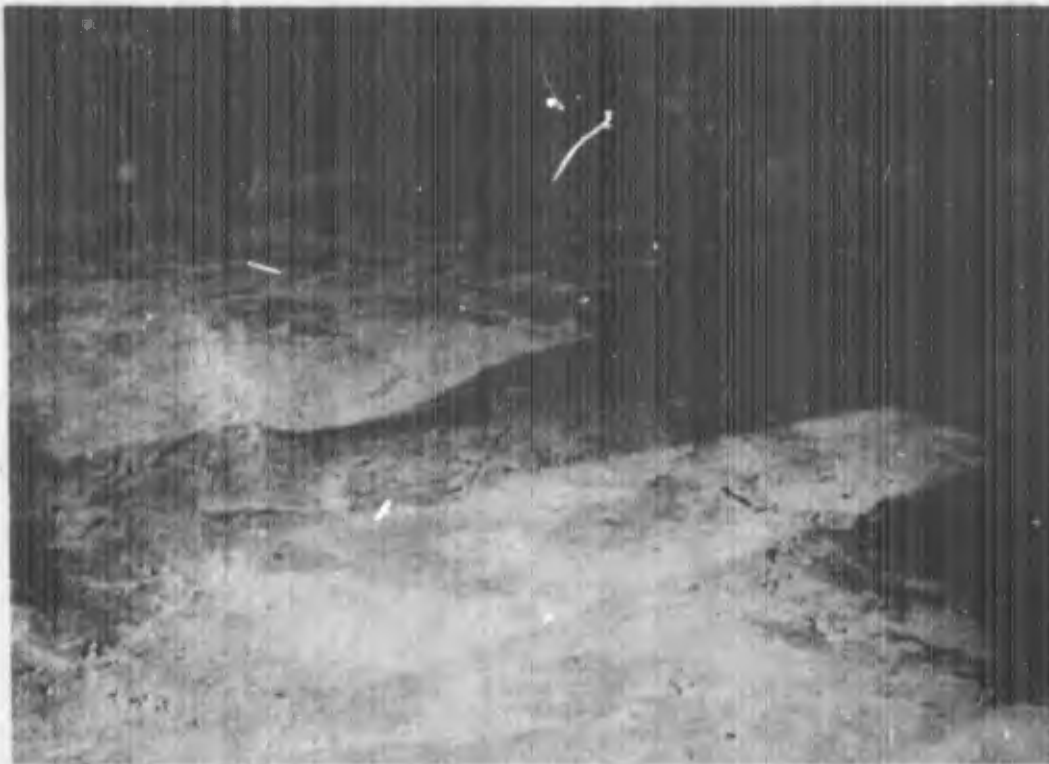


Figure 98. Test Number 1 - Deflected Shape of Soil After Removal of Failed Pad

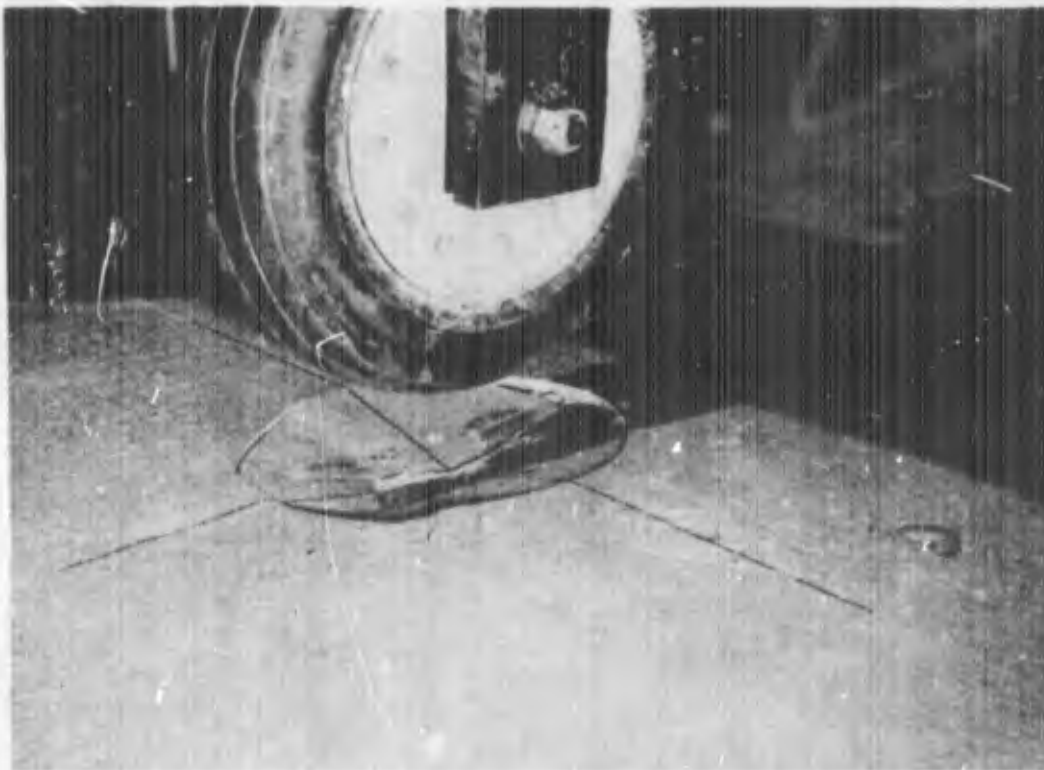


Figure 99. Test Number 2 - After Pad Failure

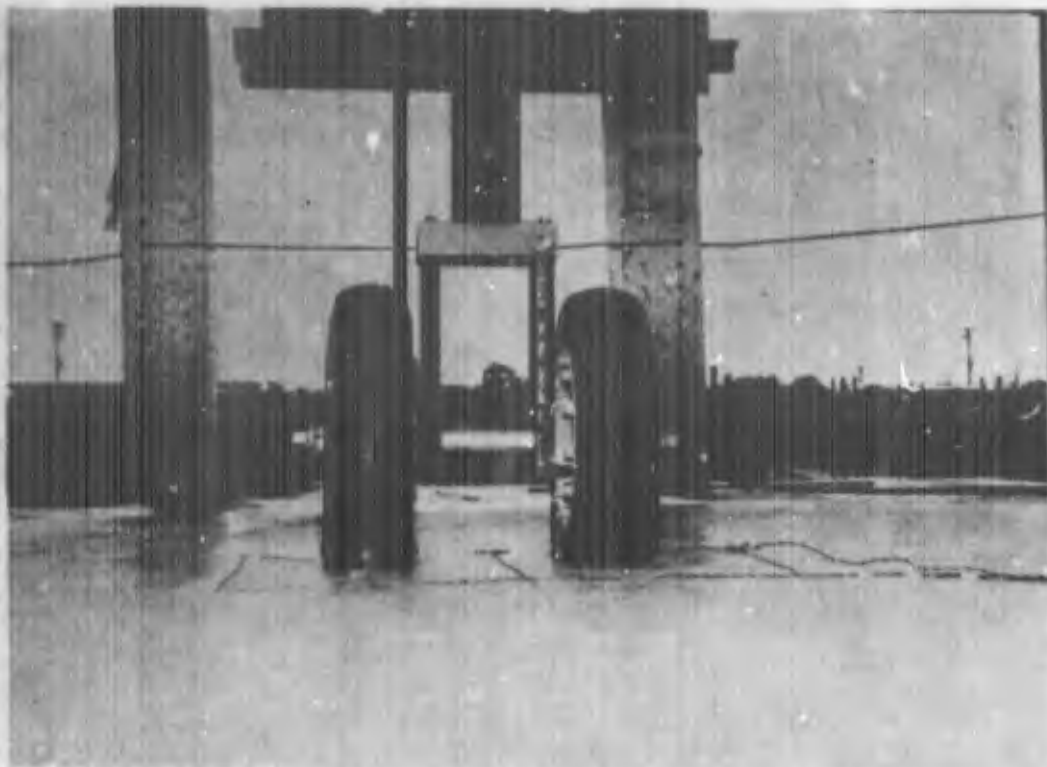


Figure 100. Test Number 3 - 30,000-lb Load Applied, 100-psi Tire Inflation Pressure

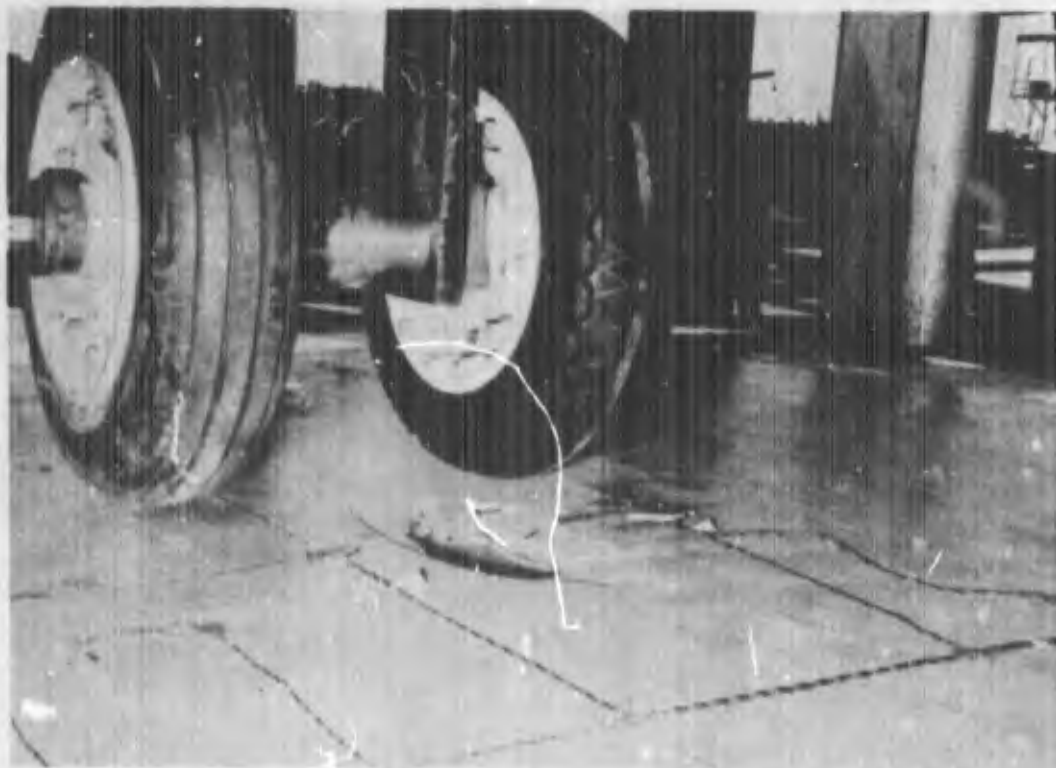


Figure 101. Test Number 3 - After Pad Failure

NOMINAL STRESS IN PAD MATERIAL - KSI

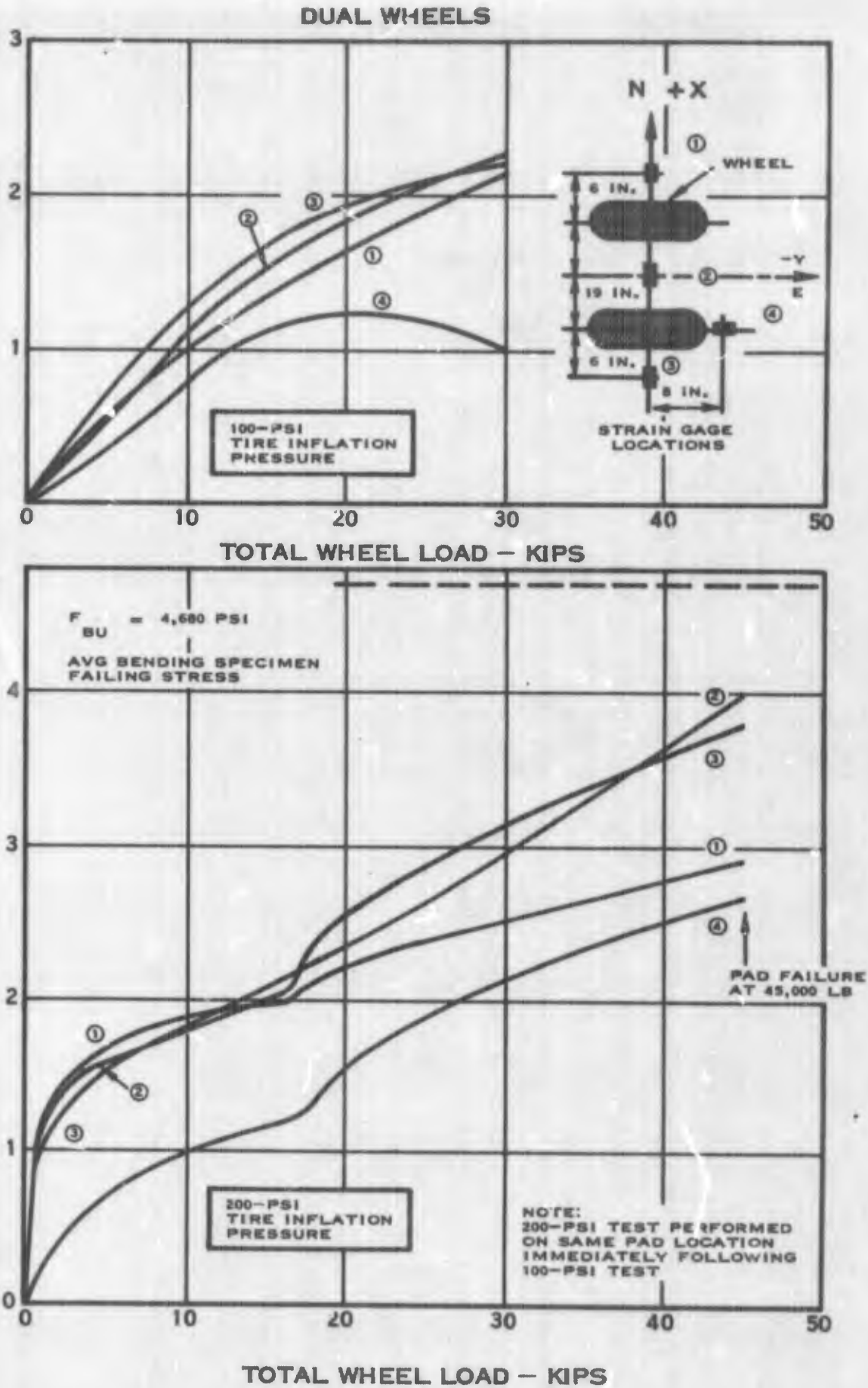


Figure 102. Nominal Pad Stress vs Wheel Load, From Strain Gage Data - Pad Test Number 3

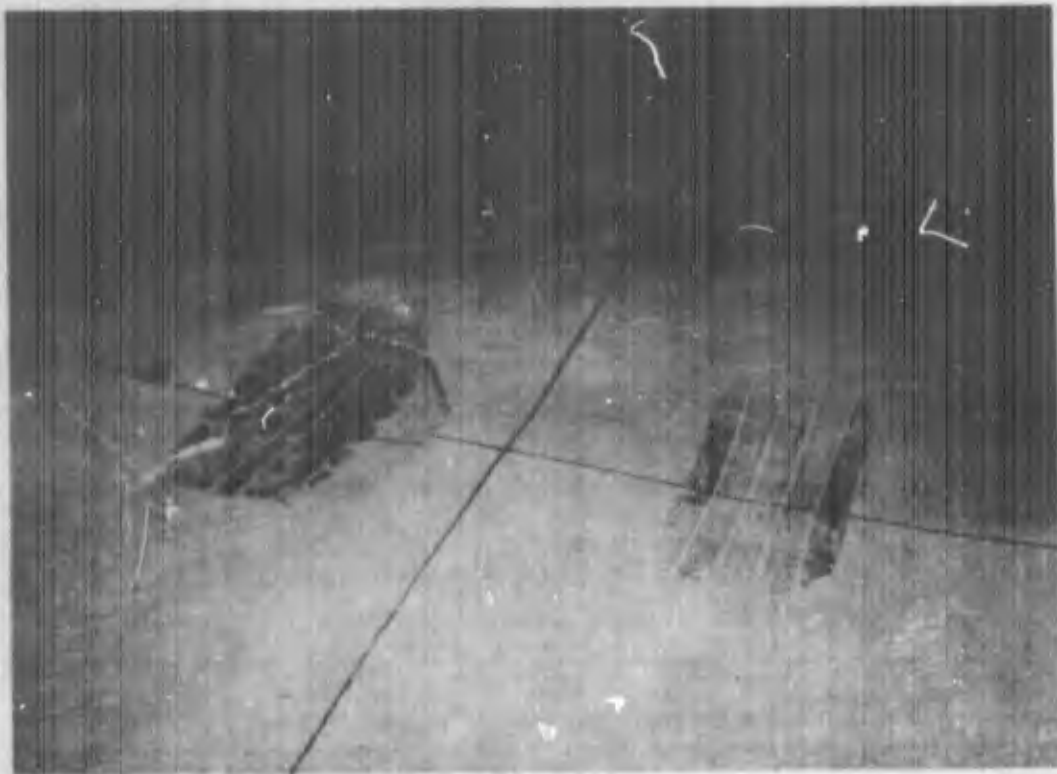


Figure 103. Test Number 4 - After Pad Failure

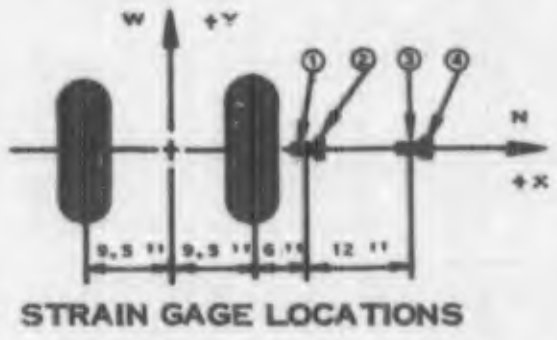
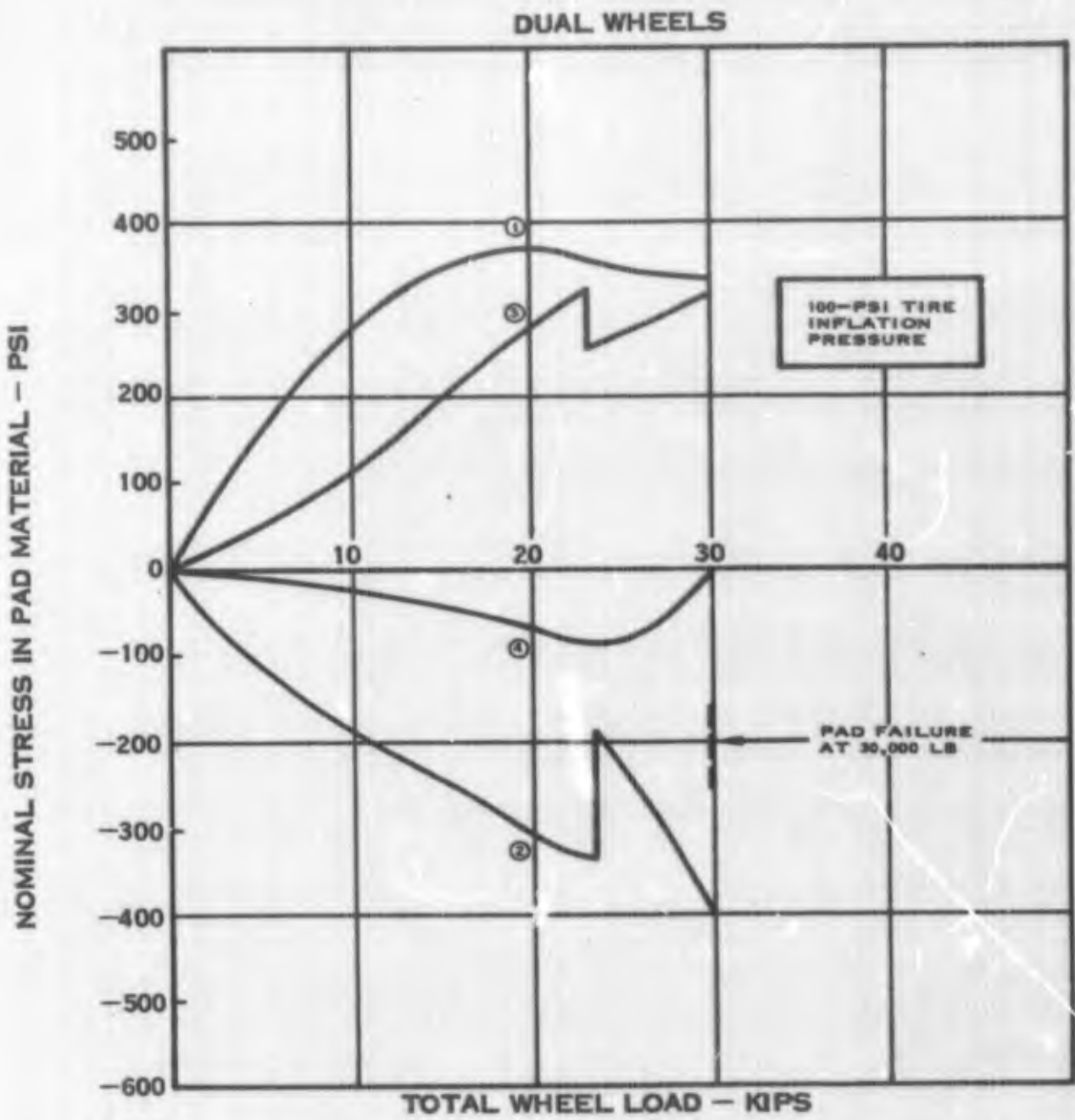


Figure 104. Nominal Pad Stress vs Wheel Load, From Strain Gage Data - Pad Test Number 4

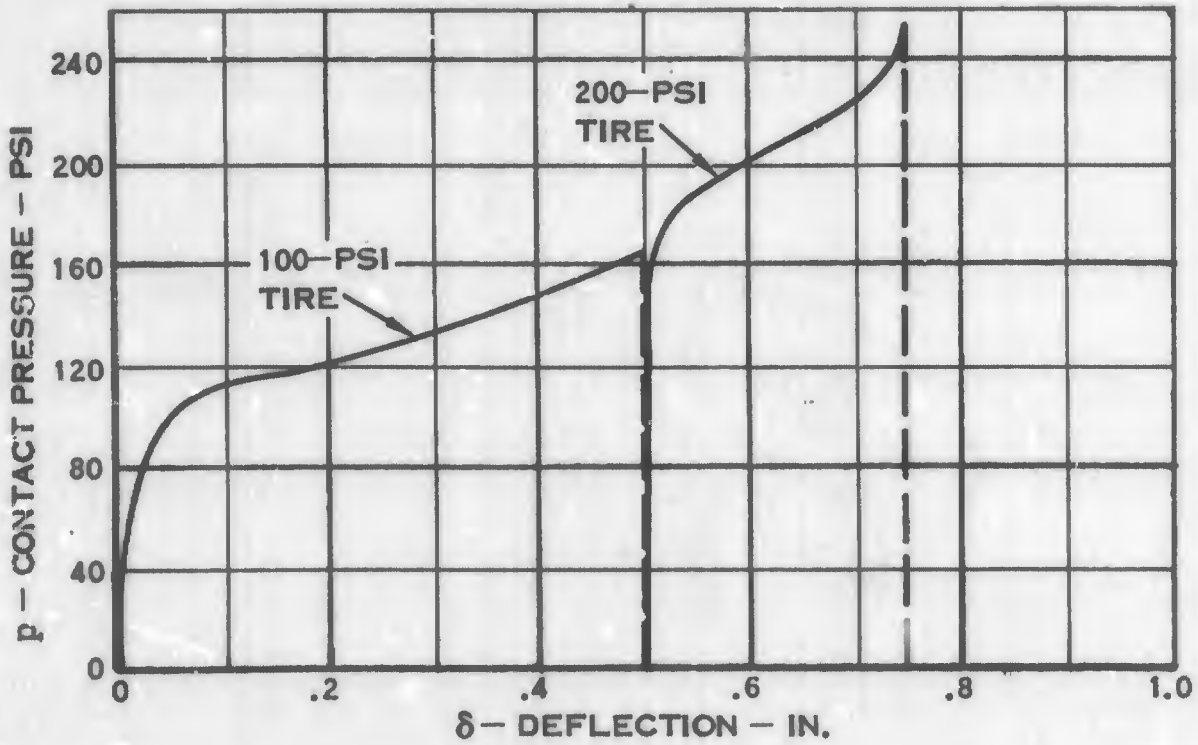
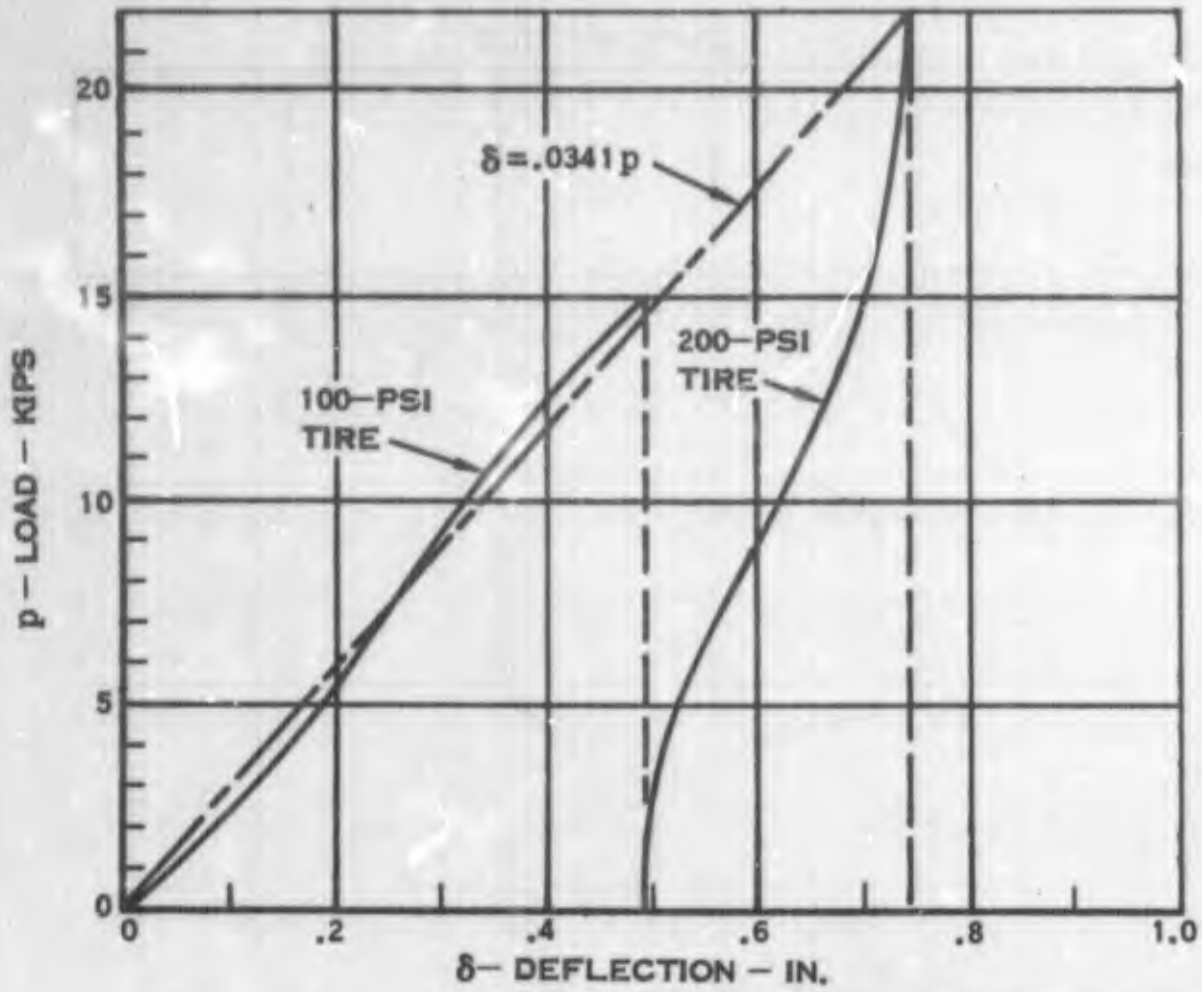


Figure 105. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 1R

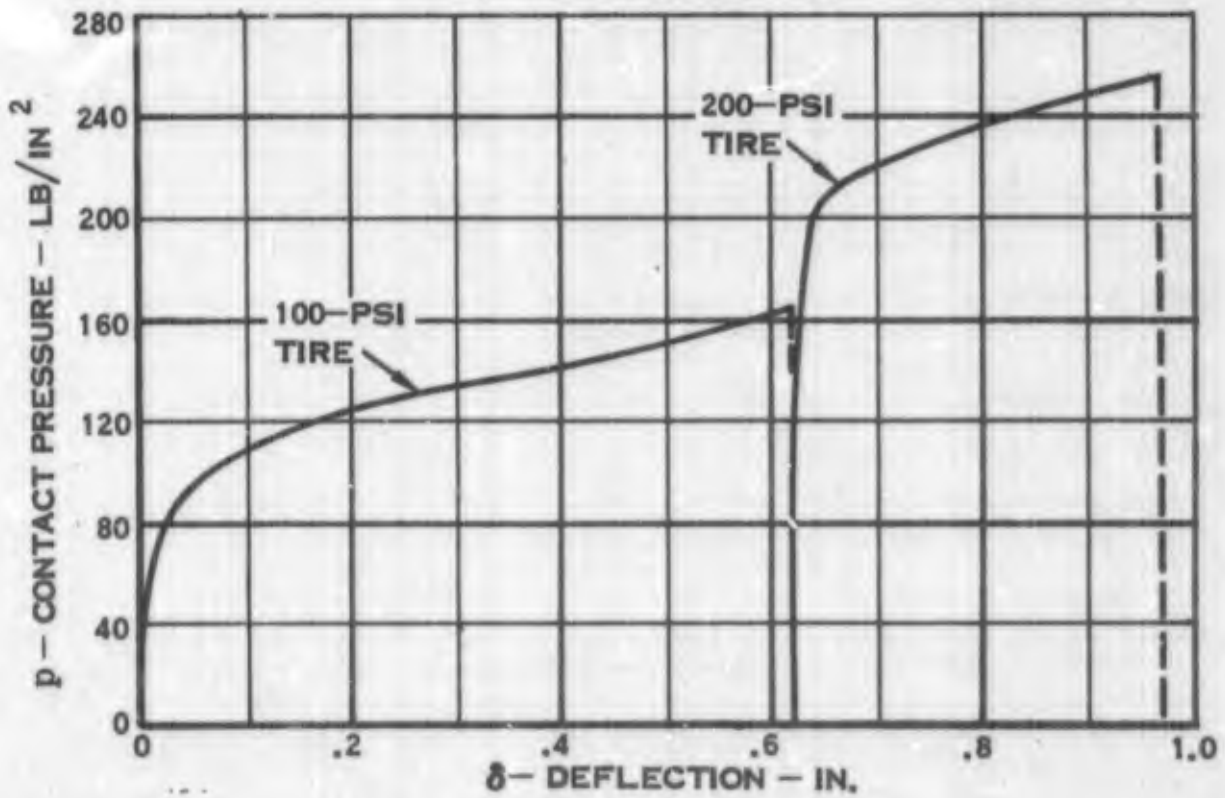
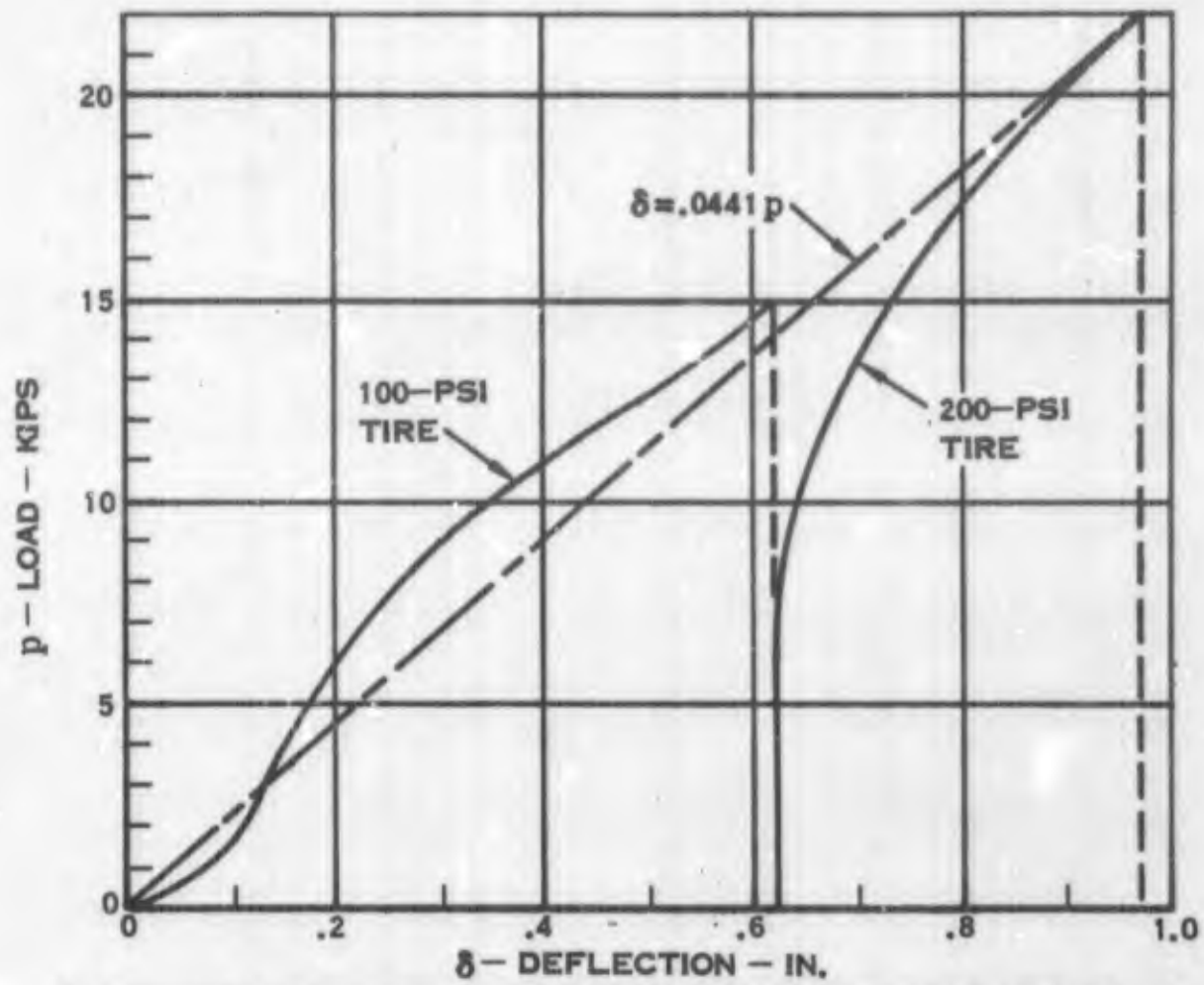


Figure 106. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 2R

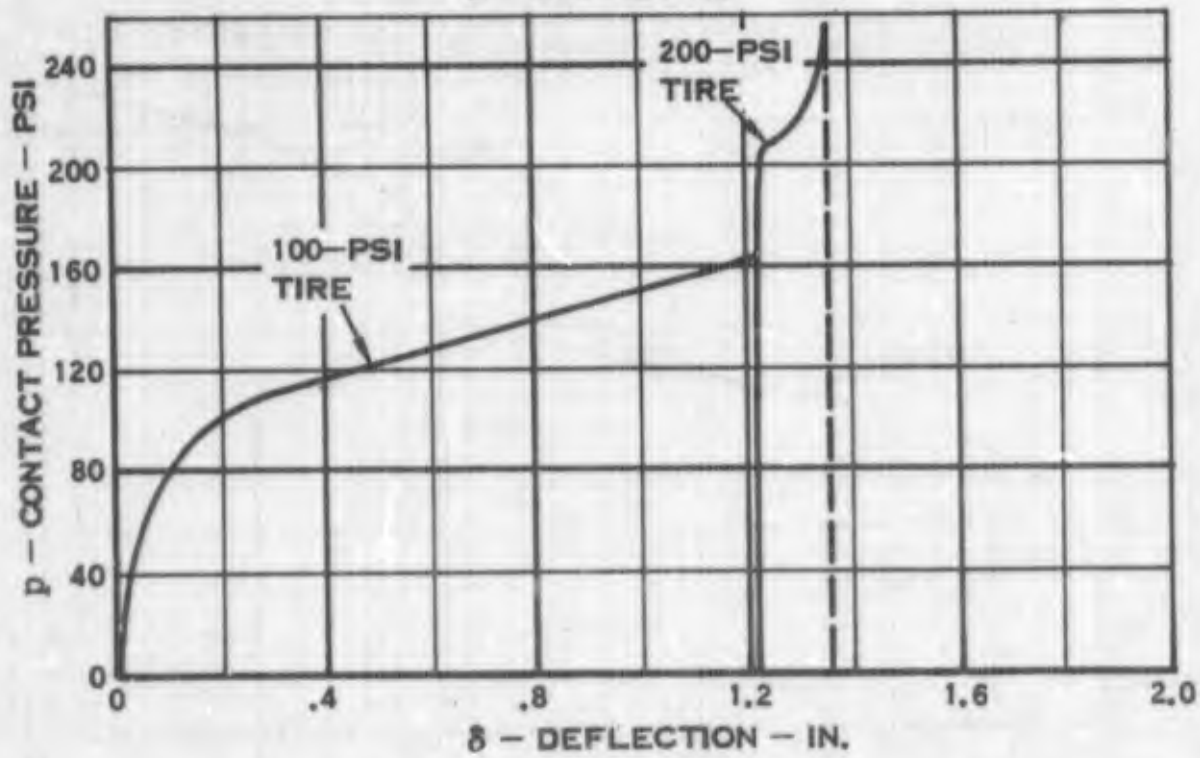
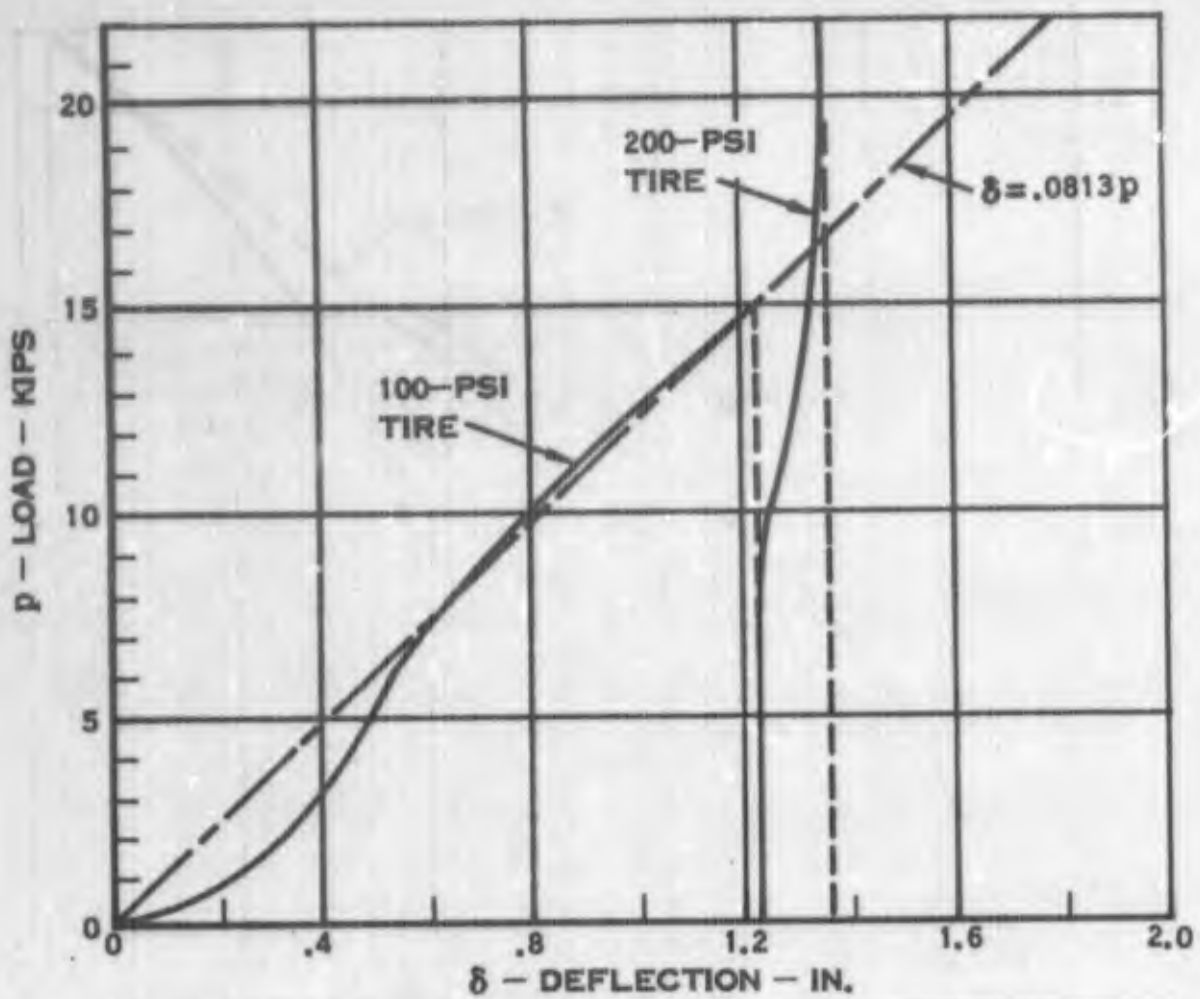


Figure 107. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 2-1/2R-1

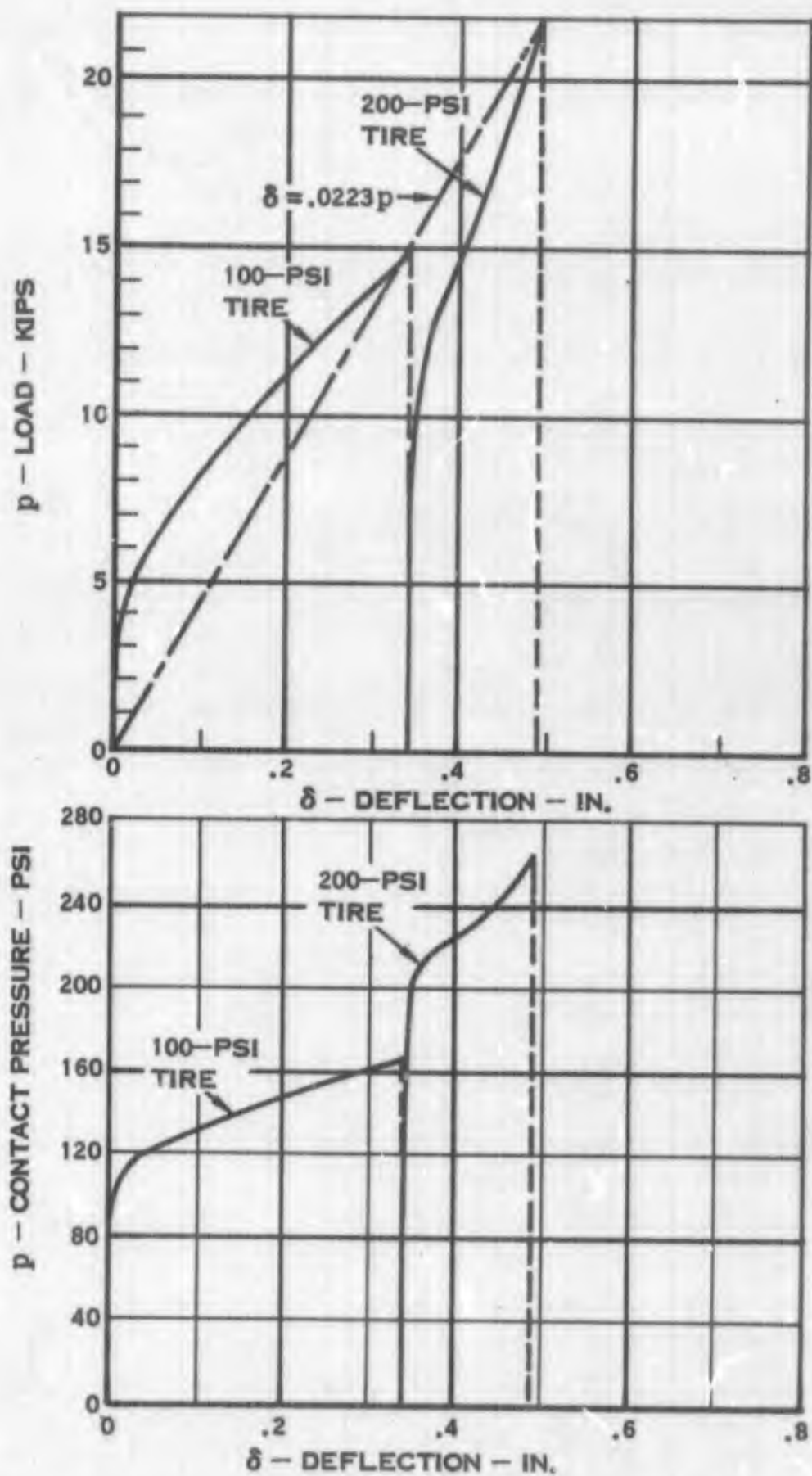


Figure 108. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 2-1/2R-2

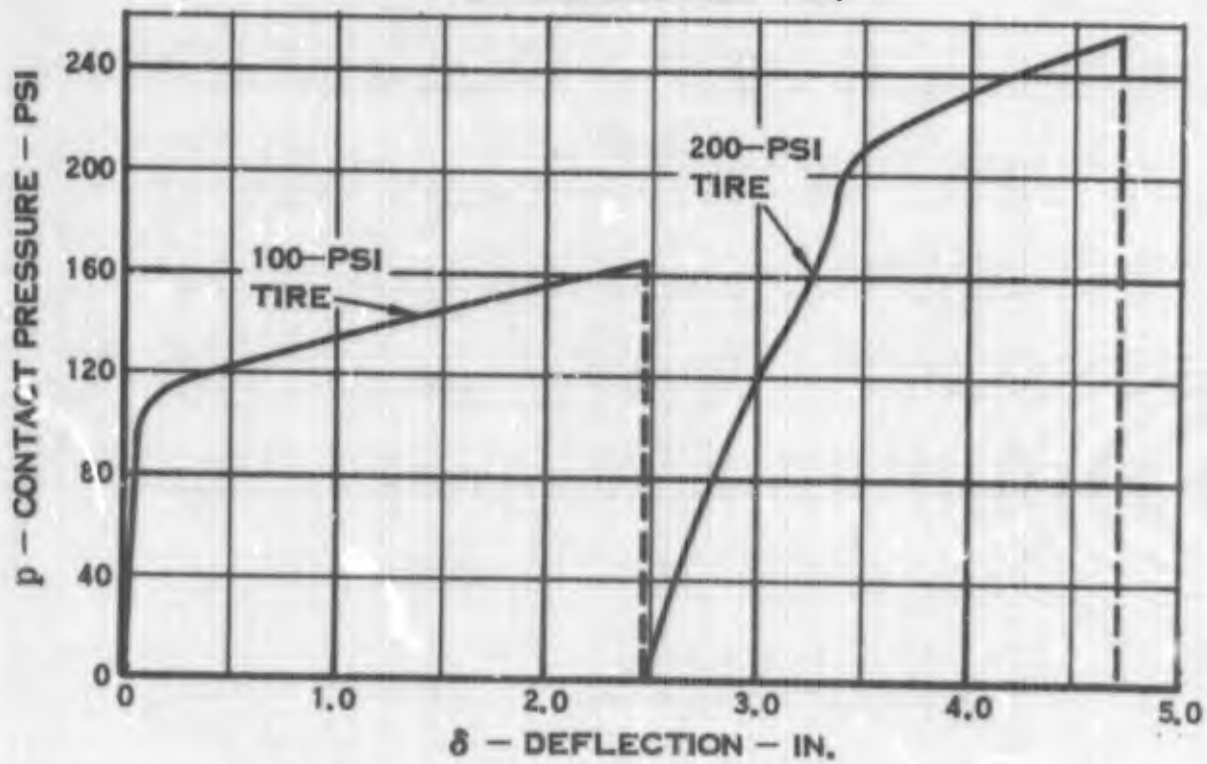
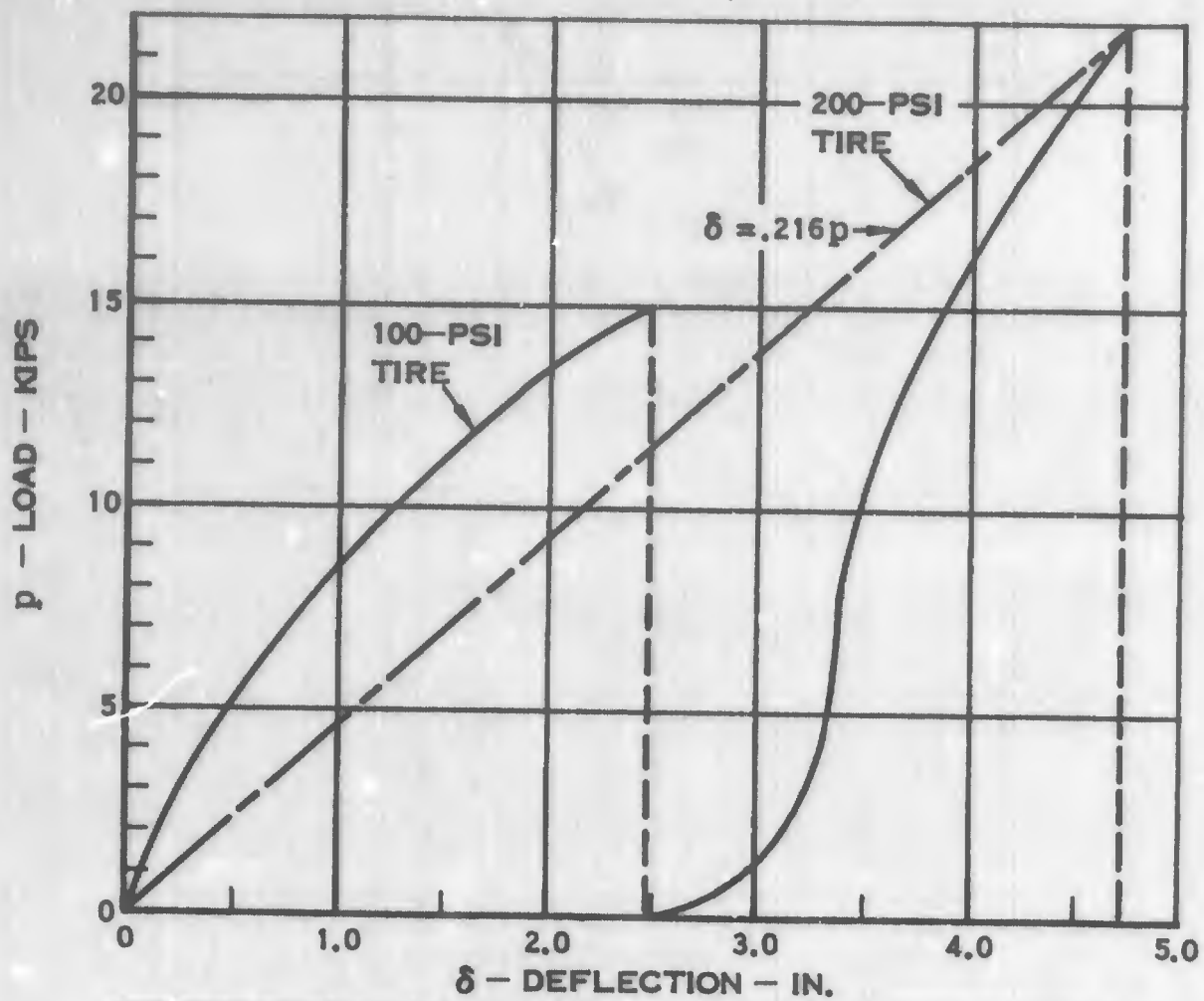


Figure 109. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 3R

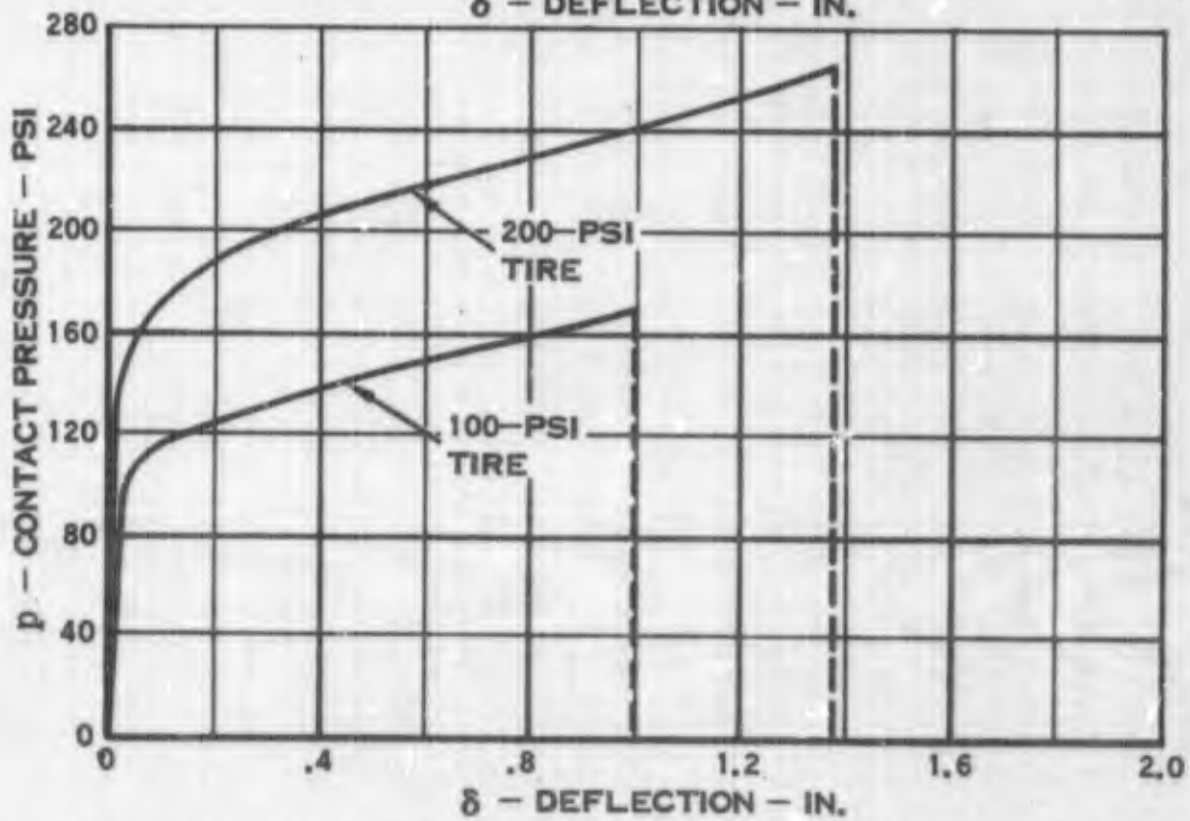
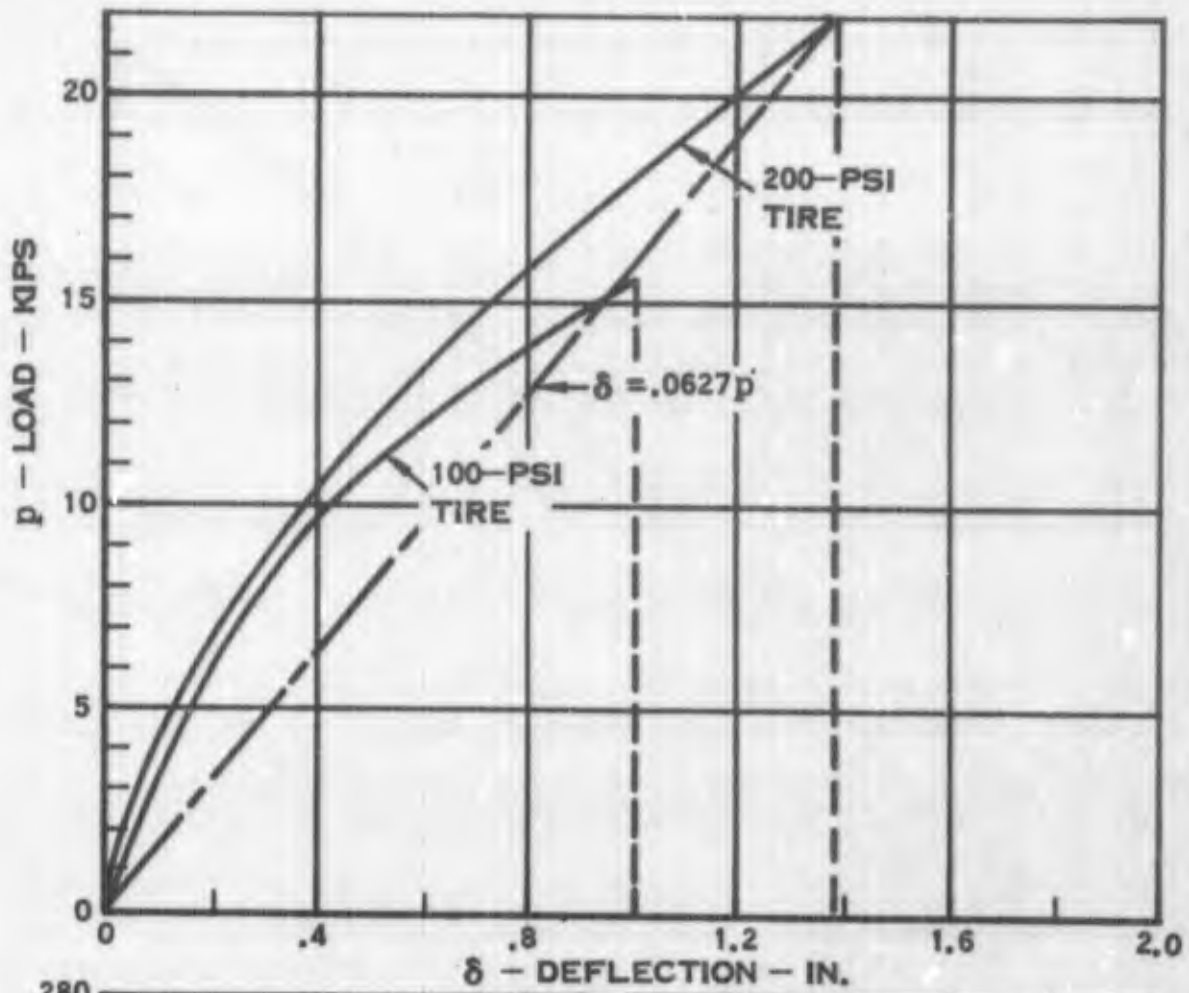


Figure 110. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 5

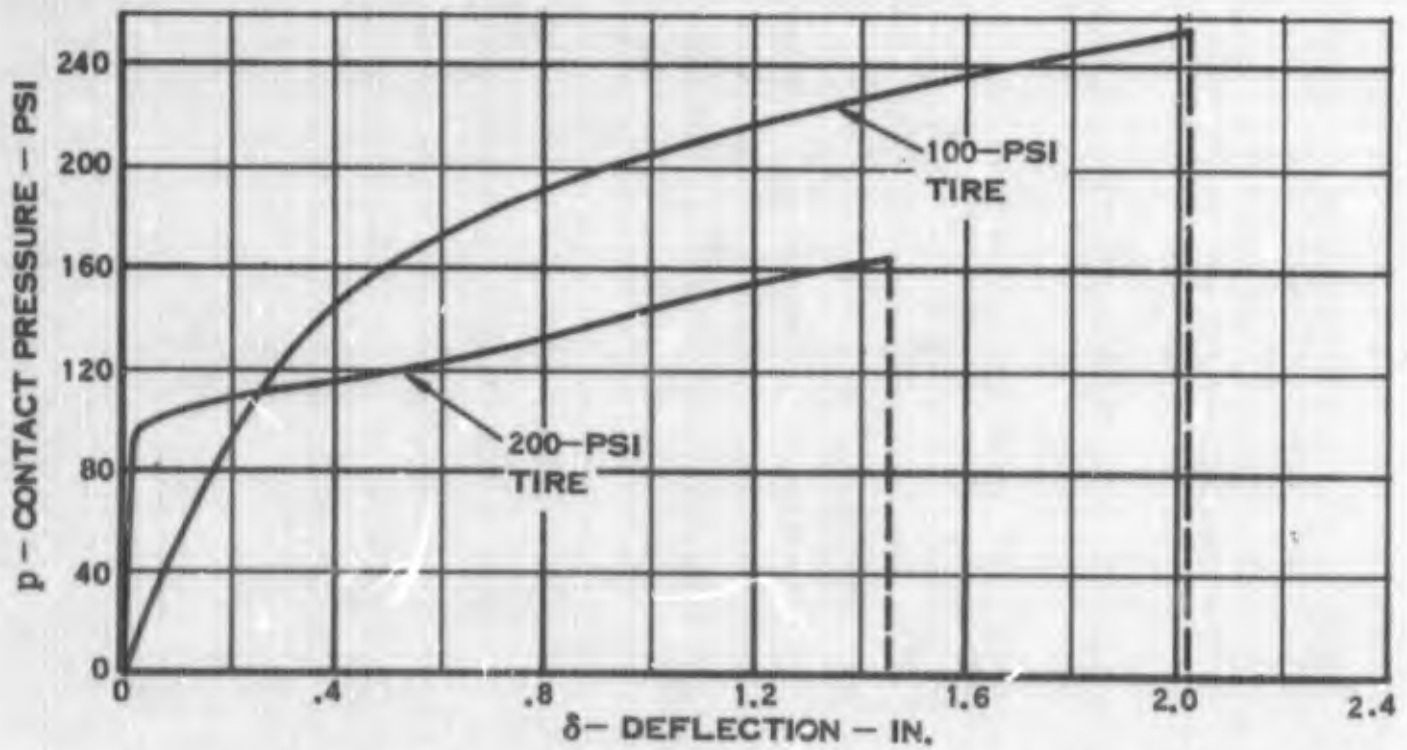
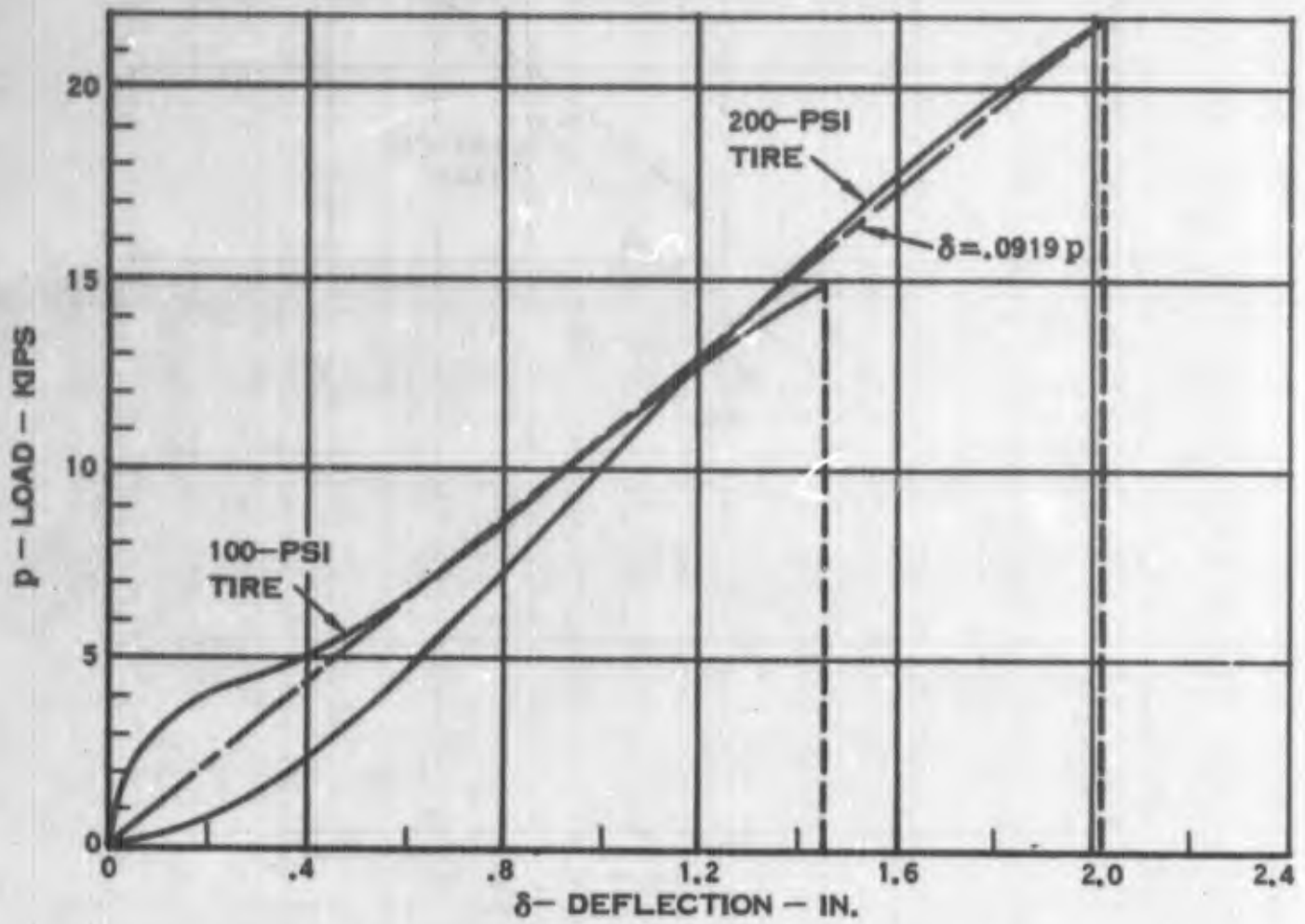


Figure 111. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 6

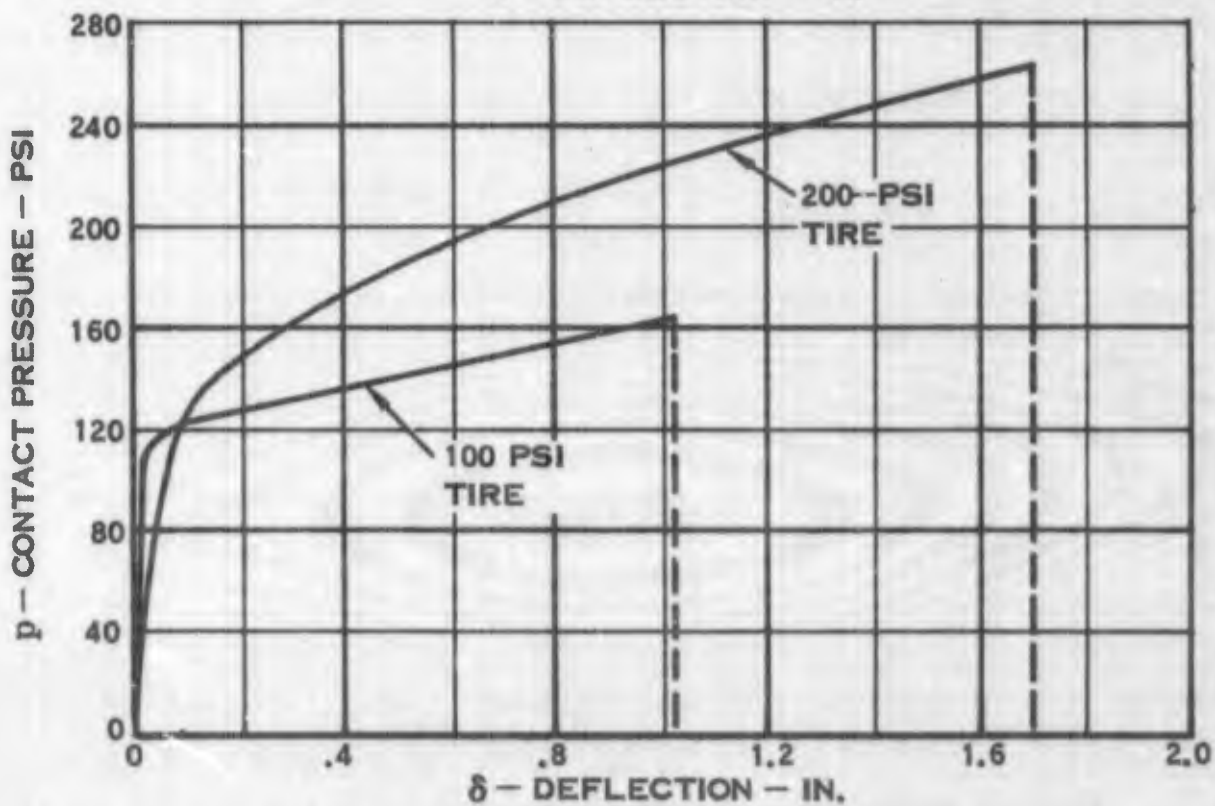
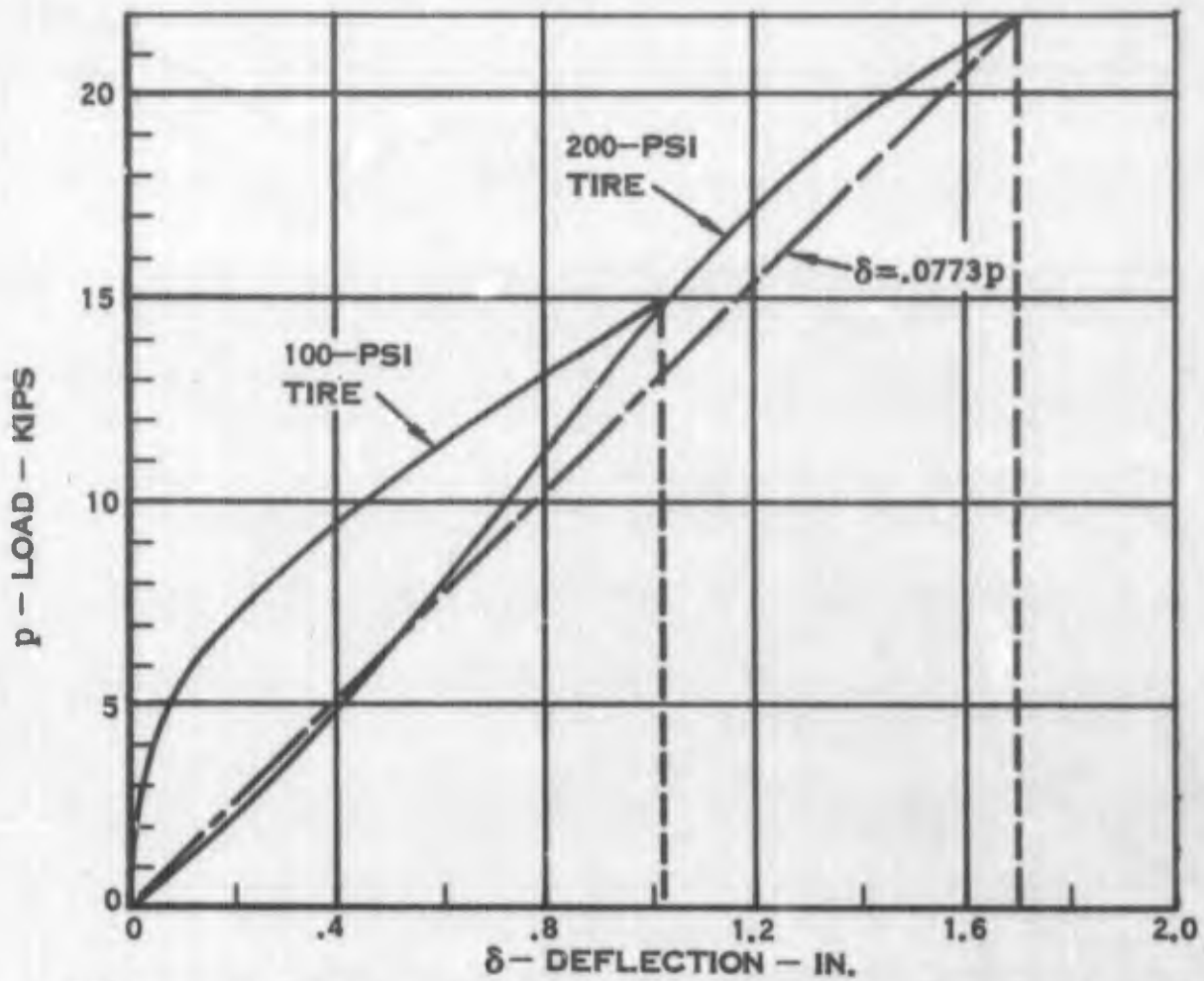


Figure 112. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 7

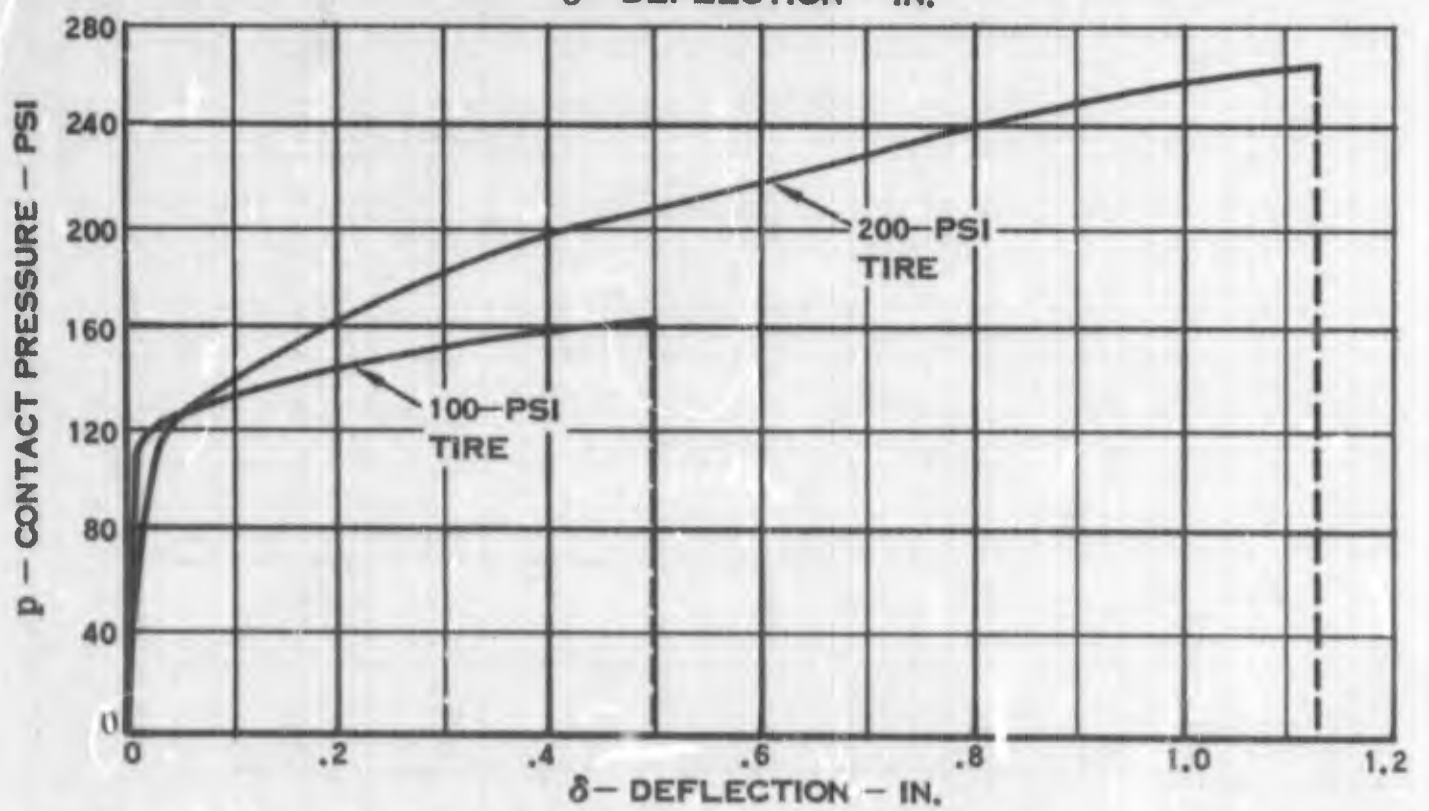
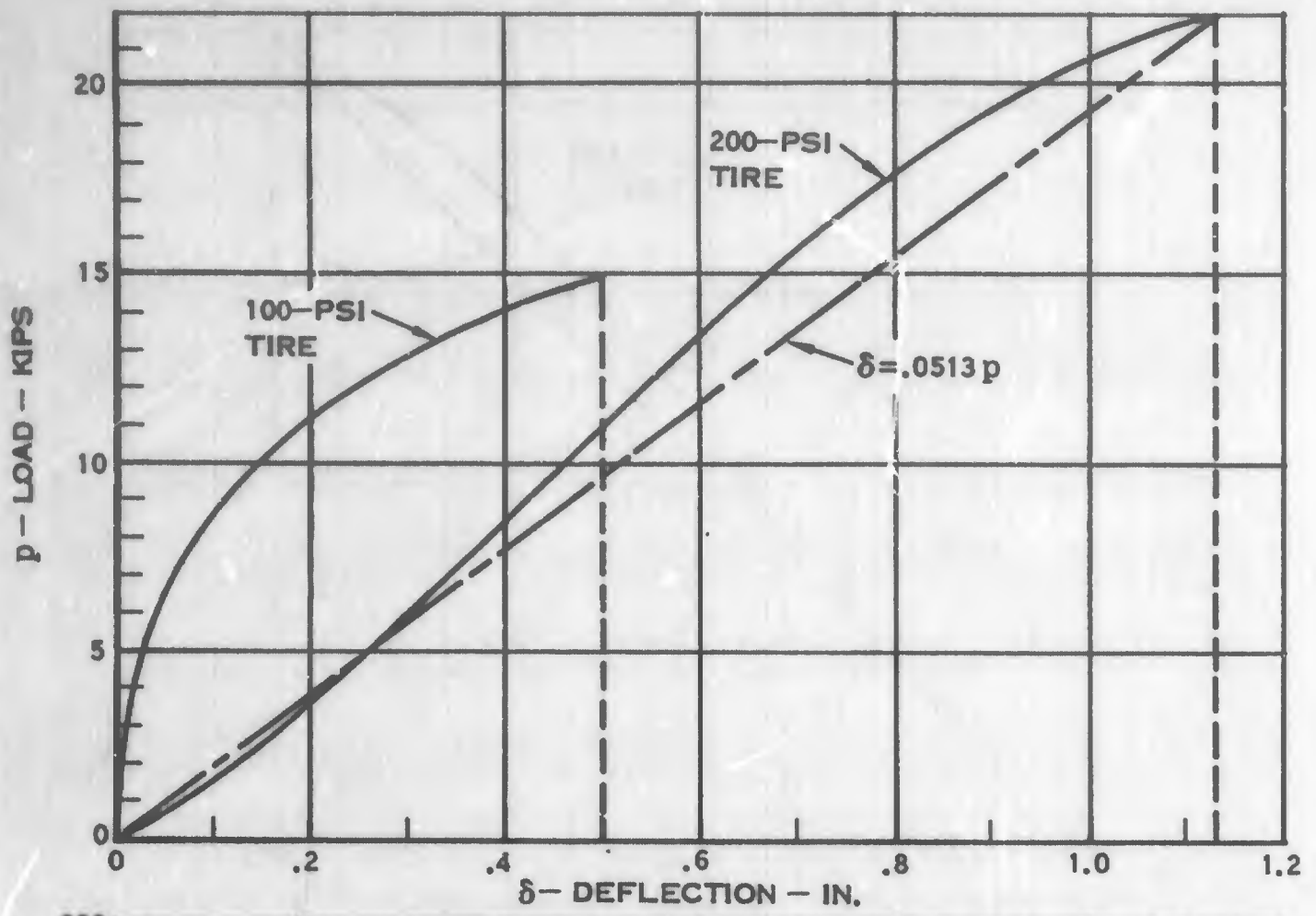


Figure 113. Wheel Load and Contact Pressure vs Deflection, Pad Test Number 8

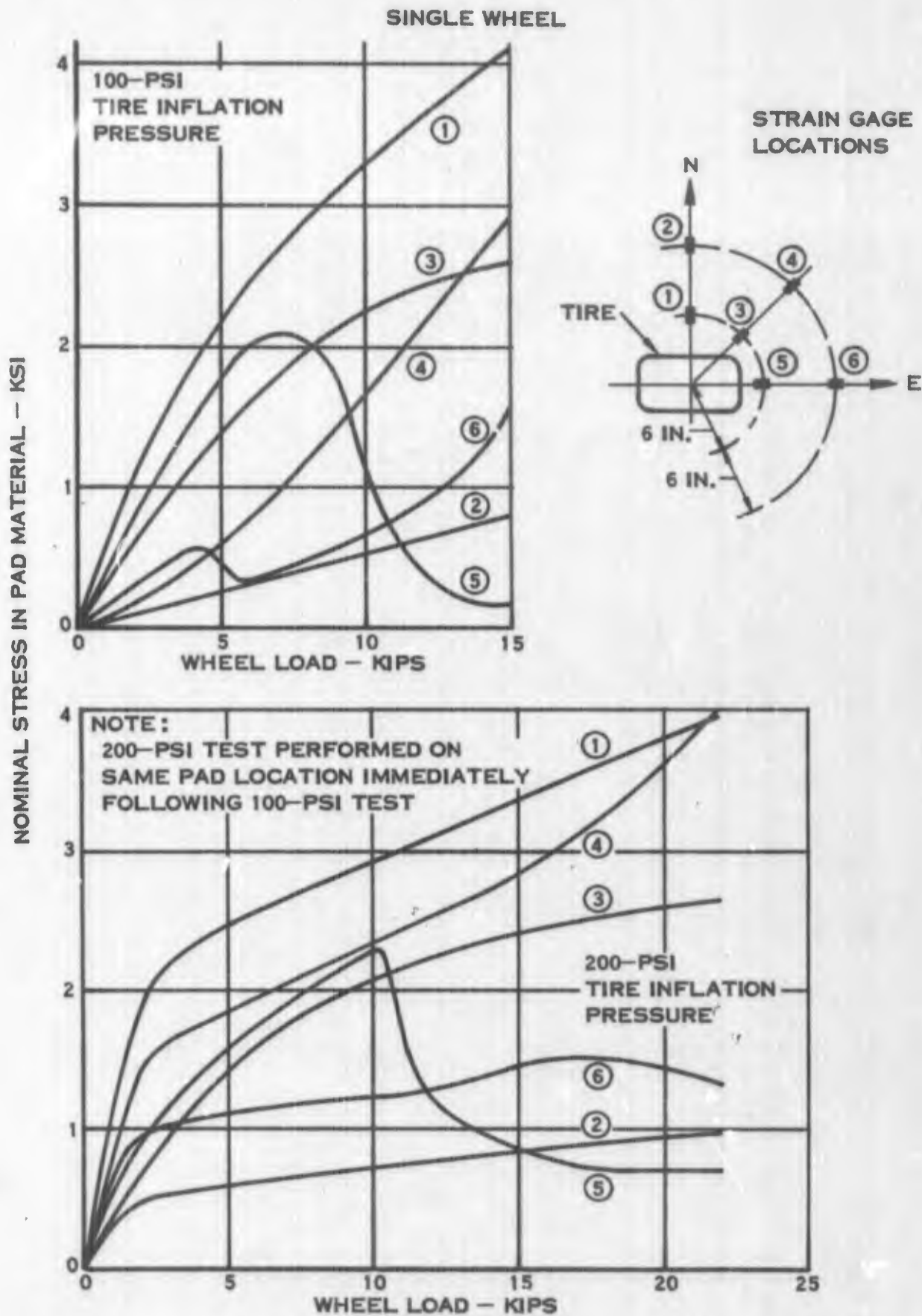


Figure 114. Nominal Pad Stress vs Wheel Load, From Strain Gage Data - Pad Test Number 1R

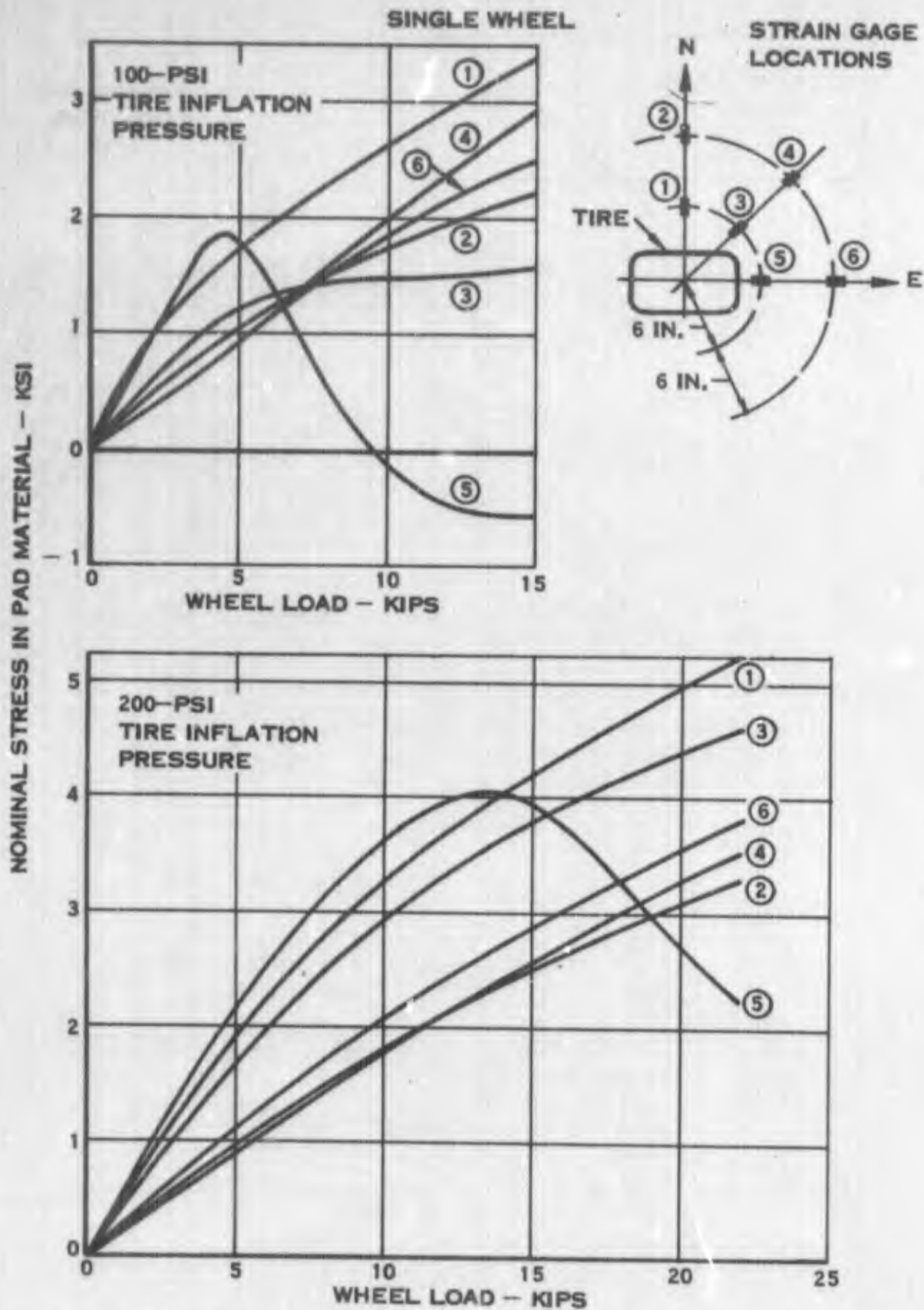


Figure 115. Nominal Pad Stress vs Wheel Load, From Strain Gage Data - Pad Test Number 7



Figure 116. Test Number 3R - 15,000-lb Load Applied, 100-psi Tire Inflation Pressure



Figure 117. Test Number 3R - Deflected Shape After Removal of Load, 200-psi Tire Inflation Pressure



Figure 118. Test Number 1R - After Removal of Load, 200-psi Tire Inflation Pressure

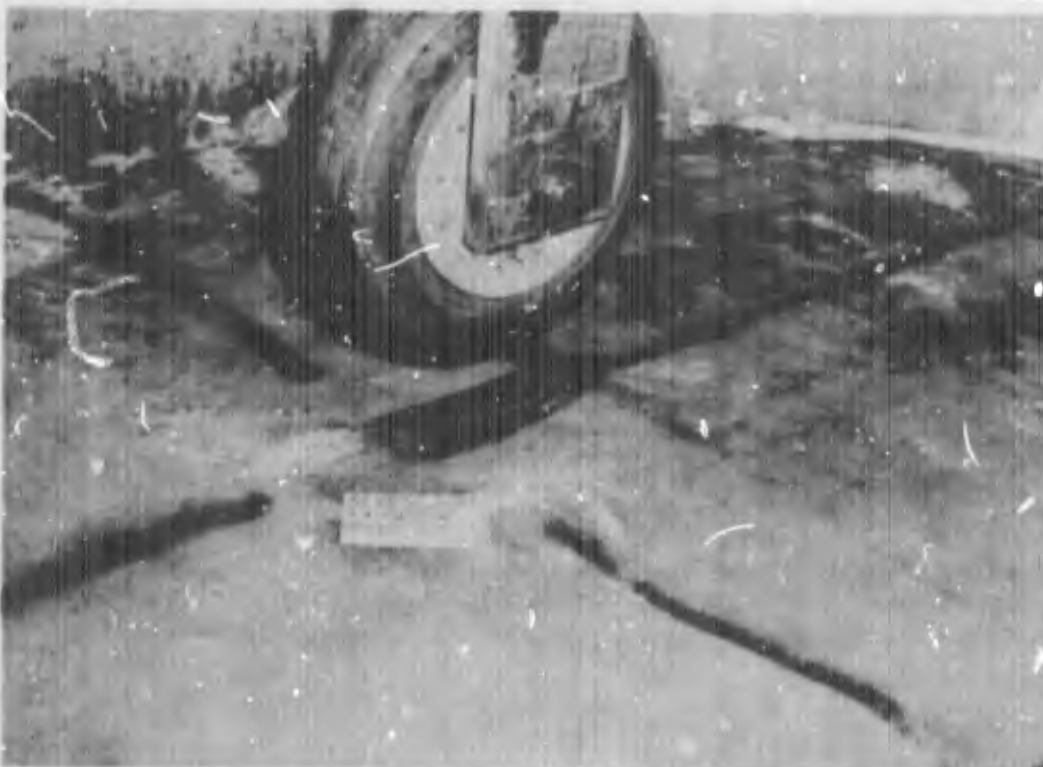


Figure 119. Test Number 2-1/2R-2 - After Removal of Load, 100-psi Tire Inflation Pressure



Figure 120. Test Number 6 - 15,000-lb Load Applied, 100-psi Tire Inflation Pressure



Figure 121. Test Number 7 - 22,000-lb Load Applied, 200-psi Tire Inflation Pressure

Table VII presents a summary of the basic data obtained from the Phase I wheel load tests described above, including, soil, pad, and wheel load data.

#### d. Analysis of Test Results

Three basic types of tests were involved in Phase I of this program: Soil Tests, Wheel Load Tests, and Element Specimen Tests.

The laboratory soil tests show Soil No. 1 to possess a better load-carrying capability than Soil No. 2. This also is true under simulated field conditions which were regulated in the soil box. Soil No. 1 had a higher CBR than Soil No. 2 for each of the wheel load tests. It must be noted that the first soil was under two major soil states while the second soil was only under one. Soil No. 1 showed no significant change in CBR when its moisture content was approximately doubled. It can also be assumed that an increase in moisture content will only increase the CBR for Soil No. 2. In general, the soil states used for the wheel load tests are indicative of the poorest conditions to be encountered in the field for these two soils.

The cone penetrometer readings vary considerably more than CBR and comparisons between the two show no definite trend (see Table VII). This observation bears out the statement made by the consulting soil engineers and by authors of several soil mechanic textbooks, that there is little correlation between CBR values and cone penetrometer readings for most types of soil. However, additional soil tests must be conducted before a definite statement can be made regarding the cone index-CBR relationship. The soil type has a very significant effect on this relationship.

The results of the ram tests show that the soil modulus is not a constant value over the entire range of loading pressure. It can be seen from Figure 88 that Soil No. 1, in its soaked states, had an average modulus of 110 psi/inch, which was fairly constant until approximately 50 psi pressure was applied to the ram. Figure 87 shows that beyond this range, the deflection increased rapidly with little increase in pressure. This phenomenon indicates that the sand has experienced a "shear" failure of a conical shape under the ram load. Both Soil No. 1 in its dry state and Soil No. 2 had a nonlinear modulus for all pressure levels. Because of their low moisture content, there was little cohesion between the sand particles which enabled the soils to displace out of the way when the load was applied.

The wheel load tests without a pad give an indication of the large deflections that occur when the wheel load is resisted by only the bare soil. Soil No. 2 deformed more than Soil No. 1 at comparable load levels. This can be seen from the load vs deflection curves shown in Figures 93 and 94. One can also see the manner in which the soil deformed. The soil deflected uniformly to a certain load level and then a small increase in load produced a very large deflection. Each time one of these plateaus was reached, a shear plane formed under the wheel.

They progressed outward and can be seen by examining the soil cracks in Figure 91.

With addition of a pad, the deflections were reduced by approximately a factor of 12 for the average of all the wheel load tests. This shows that in general, any of the pads fabricated for this program were a significant improvement over applying the wheel loads to the bare soil. Even with the thinnest pad, No. 3R, the soil would deflect about one-sixth that using no pad (assuming a comparable load level).

The maximum deflections varied considerably for each pad test since the soil condition, type of pad, and pad thickness were not constant throughout the testing program. Definite correlations incorporating these variables will not be made at this time but in the latter phases of the program.

In general, comparable pads on Soil No. 2 deflected more than those on Soil No. 1. This is to be expected since the second soil has a lower CBR than the first soil. Figures 105 through 113 show that the relationship between load and deflection is not a linear one. However, an approximate linear relationship can be established for each pad by joining a straight line between the origin of the load vs deflection curve and the coordinate at the maximum applied load. As an example, Figure 105 shows that the following relationship between load and deflection can be established for pad test No. 1R:  $\delta = .0341 P$ , where  $\delta$  is in inches and P in kips. In this case, the line was drawn from the origin to the coordinate (22k, .75 in.). The empirical formula is in close agreement when using the 100-psi tire but unconservative in the early stages of loading for the 200-psi tire. However, it must be remembered that the 200-psi tire was loaded in the same pad location after removing the 100-psi tire load. This type of empirical formula agrees favorably for each of the pads. Figures 105 through 113 show this relationship for pad tests No. 1R through No. 8. A certain amount of judgement must be used to form a reasonable yet conservative correlation between load and deflection.

From the strain gage data, the nominal stress was calculated by multiplying the strains by the average modulus of the pad. The results give an indication of the stress level on the upper surface of the pad for each load increment. These nominal stresses do not completely describe the true stress state since the pads were not instrumented with strain rosettes. To get a complete picture of the stress distribution in the pads, strain rosettes would be required on both the upper and lower pad surfaces at various locations.

Inspection of the curves in Figure 102 shows that the stress is tensile at each of the gage locations. For the 100-psi tires, the stresses at gages 1, 2, and 3 increase with load at a similar rate. At gage 4, the stress reached a maximum at a 20,000-pound load and then started to decrease. The stress at all four gages increased very rapidly with little load using the 200-psi tires. A discontinuity in each curve can be seen at a total load of about 17,000 pounds. The stresses at those points are at approximately the same level as the maximum stresses using the 100-psi tires.

These observations clearly indicate that the depression left in the soil by the previous loading prevented the pad and soil from acting together until the gap was closed.

The strain gage results from pad test No. 4, as shown in Figure 104, show a significantly lower stress level than for test No. 3. The gage layout pattern was changed from that used for the previous test but a comparison of gage 1 from each pad shows this difference in stresses. Both pads were loaded with the dual wheel configuration and pad No. 4 was slightly thicker than pad No. 3. Gages 2 and 4 were oriented in the transverse direction and these stresses were compressive up to failure. The discontinuities at a load of about 23,000 pounds were caused by the initiation of cracks in the pad which progressed up until failure.

Pads No. 1R and No. 7 were both instrumented in the same way with each gage oriented in a radial direction with respect to the center of the single wheel loading point. Both pads strained in a similar manner as can be seen in Figures 114 and 115. The stresses were primarily tensile with those at a six-inch radius being generally larger than at a twelve-inch radius. The stresses from gage 5 increased to a maximum value and then decreased with additional load. The gage 5 stress in pad No. 7 with the 100-psi tire went to compression at 9,600 pounds. The tire footprint ended up completely covering gage 5 on both pads. Here again on pad No. 1R we can see the effect of the gap left between the pad and the soil when the 200-psi tire was applied. Pad No. 7 was tested at two separate locations and therefore did not experience this effect.

The results of the strain gage and deflection data give an indication of the stress distribution on the upper surface of the pad. Both radial and circumferential stresses decrease as the distance from the center of the load gets larger. The radial stresses are tensile except in the immediate area of the tire footprint where they are in compression and the circumferential stresses are compressive. The stress pattern as seen in gage 5 of pads No. 1R and No. 7 along with the large deflections (on the order of 5 times the pad thickness) indicates the presence of membrane stresses. It can be concluded that the upper surface of the pad is defined by a biaxial state of stress formed by a combination of plate bending and membrane forces.

The element specimen test results as summarized in Table IX show a significant amount of scatter among the four specimens of each pad. The average scatter between the maximum and minimum values is 2.0 for tensile strength, 2.0 for flexural strength, 1.7 for tension modulus and 2.2 for bending modulus. The specimens cut from pads No. 1R through No. 8 had 60% more scatter than those from pads No. 1 through No. 4 and those fabricated in Europe. These large variations in material properties are due to a number of factors. The amount of sprayed glass was not uniform from point to point in the pads nor were the fibers oriented in an isotropic manner. It was also difficult to keep the woven roving at a constant level due to the soil surface irregularities. The thickness variations had a definite effect since the pads were composite structures rather than being homogeneous. Therefore the mechanical properties are not independent of the pad thickness. The scatter in thickness for each pad can be seen in

Table VIII. Future improvements in glass dispersion and uniformity in the resin will decrease the scatter in the landing pad mechanical properties.

From structural standpoint, there were two basic types of pads used in Phase I. Those fabricated initially, pads No. 1 through No. 4 and the European pads, consisted of spray roving and a heat resistant resin. Those constructed after the remote site tests in Europe, pads No. 1R through No. 8, used a combination of woven roving, sprayed glass, and a more flexible resin than before. The post-Europe pads were approximately three times stronger and 25% more flexible than the previous type. The results of the English and German pad specimen tests closely agreed with those cut from pads No. 1 through No. 4. For all pad types, the tension modulus was approximately equal to the bending modulus, and the flexure strength was about twice the tensile strength. These conclusions are evident upon examination of the element specimen test results given in Table IX .

The Phase I testing program demonstrated the relationship between a pad's load-carrying capability and the previously discussed variables. From the results, a functional design criteria can be generated. This will be done after additional data from Phases II and III becomes available.

## 2. SITE SIZE AND SHAPE CRITERIA

The primary purpose of the Rapid Site landing pad is to prevent damage to VTOL aircraft by minimizing erosion of the ground surface from the downwash of the VTOL aircraft in hover mode. To insure that erosion is prevented or kept within acceptable limits, a knowledge of factors influencing erosion is required. It is generally accepted that erosion caused by downwash is functionally related to the downwash velocity and velocity profile at the point where erosion occurs. Kuhn showed in NASA TND 56 that the erosion threshold for a given ground surface (snow, sand, water, etc.) may be established in terms of a maximum allowable dynamic pressure occurring in the downwash at a given point. Therefore, if the variation in dynamic pressure along the ground is known throughout the downwash flow field, the areas of the ground surface which will be eroded may be established based on the particular ground surface erosion threshold.

In previous work under Air Force Contract Number AF33(615)-2367, a method for calculating landing pad diameter as a function of downwash and erosion characteristics was developed based on theories and experimental data for downwash created by a single uniform jet impinging normally on a flat plate. This method of predicting downwash dynamic pressures and the resulting pad size required to prevent erosion does not include the effects of multiple jets but assumes that the flow field behaves as if it were produced by a single jet. Therefore, a series of studies were undertaken to refine the method to include the effects of multiple jets since the present program is concerned with multi-engine aircraft. The tasks undertaken to establish the data necessary for refining the method were:

A survey of downwash and erosion literature

Model flow field studies both at the University of Texas and at ITV

Model downwash fence studies

Actual site flow field measurements

These tasks are discussed in the following paragraphs. The symbols used on the curves and in the discussion are:

D	Diameter of equivalent single uniform jet
H	Height of exhaust exit above ground
$q_{max}$	Maximum ground dynamic pressure at a given location
$q_g$	Average exhaust exit dynamic pressure
r	Radial distance from center of flow field
$r_f$	Distance from center of flow field to fence
$\theta$	Angle between r and forward portion of fuselage centerline

Pertinent characteristics to be used with the aircraft considered in this investigation are:

Aircraft	D (ft)	$q_E$ (psf)	REQUIRED PAD DIAMETER* (FT)	
			Theory	Model
P. 1127	2.91	1121	125	131
VJ101	2.91	1352	136	146
XC-142	21.9	55	20	223
DO-31	5.88	912	229	---

a. Literature Surveys

Two literature surveys were initiated to acquire information applicable to sizing the rapid site pads:

- (1) A search for erosion information
- (2) A search for downwash flow field information

The sources of downwash flow field information considered to be directly applicable to the problem of sizing the rapid site pads are listed below along with a summary statement of the contents of each report. The search for erosion information yielded no new erosion data.

(1) Brady, W. G. and Ludwig, G., Theoretical and Experimental Studies of Impinging Uniform Jets, Trecom Tech. Rep. 63-11. This report contains a theoretical treatment of the flow field of a single uniform jet and substantiating experimental data. The theoretical predictions of radial velocity decay and ground boundary layer velocity profiles are in good agreement with the experimental data which are presented for nozzle heights up to 4 diameters and radial distances out to 1.8 diameters. This range of variation is considered to be within the "near field" portion of the flow field.

(2) Higgins, C. C. and Wainwright, T. W., Dynamic Pressure and Thrust Characteristics of Cold Jets Discharging from Several Exhaust Nozzles Designed for VTOL Downwash Suppression, NASA TN-D-2263, April 1964. This report contains "far field" downwash data, nozzle heights to 30 diameters, and radial distances to 9 diameters.

(3) Walker, S. C. and Wolfe, G. W., Results of a Small Scale Downwash Test Program, LTV Report No. EOR-13108, December 1960. This report contains a quantity of "near field" experimental data.

\*Prediction of pad diameter is based on a  $q_{max}$  at the edge with no fences of 3 PSF which is the erosion threshold of dry sand.

(4) Isely, F. D. and Wolfe, G. W., A Method of Calculating the Airflow Field Resulting from VTOL Aircraft Downwash, LTV Report No. BOR-13112, December 1960. This report contains a method of calculating the velocity at any point in the flow field of a single uniform jet directed perpendicular to a flat surface. The method resulted from a combination of theories and experimental data and, as a result, is semi-empirical. Downwash radial velocity variations predicted by the method are in good agreement with the experimental data of items (1) through (3) above.

(5) Turner, G. D., The Interaction of Two Parallel Sonic Jets Impinging on a Flat Plate, M. S. Thesis, University of Texas, January 1965. This report contains a quantity of ground plane static pressure data and radial velocity data for various nozzle spacings and nozzle heights.

(6) Newsom, W. A. and Tosti, L. P., Slipstream Flow Around Several Tilt Wing VTOL Aircraft Models Operating Near the Ground, NASA TN-D-1382, September 1962. This report provides qualitative and some quantitative downwash data for flow fields generated by VTOL aircraft with two and four propellers.

(7) O'Neal, G. E., A Method of Calculating VTOL Aircraft Landing Mat Size, LTV Report No. 2-53910/5TM-7, April 1965. This report contains a comparison of the experimental data contained in items (1) through (5) above with the results of the theory of item (4). The agreement is considered good. The method of estimating landing mat size is based on the theory of item (4).

The above listed references contain information which is directly applicable to either understanding or predicting the behavior of VTOL aircraft downwash flow fields. A bibliography of all the references surveyed is included in the appendix in the Mid-Point Report.

#### b. Model Flow Field Studies

The University of Texas performed downwash flow field tests using models of the P.1127, VJ101, XC-142, and DO-31 aircraft. The tests were conducted using the University's model downwash flow facility which has an airflow capacity of one pound per second and will properly simulate the required downwash dynamic pressures. The instrumentation is sufficient for measuring the downwash ground jet dynamic pressure variation.

Models of the above aircraft were constructed with nozzle arrangements as shown in Figures 122 through 125. Results of the tests of the P.1127, VJ101, and XC-142 models are shown in Figure 126 through 131.

The data obtained in the model tests consist of ground flow dynamic pressure,  $q_{max}$ , versus distance along radial lines oriented 0, 30, 45, 60, 75, 90, 120, 150, and 180 degrees relative to the centerline of the model for various model heights above the ground. The data presented in Figures 127, 129, and 131 represent the maximum extent of the dynamic pressure contour lines. In other words, for a given allowable  $q_{max}/q_E$  at

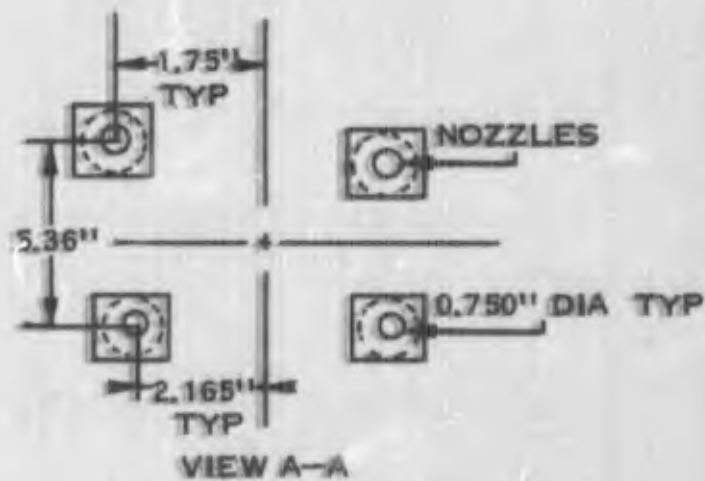
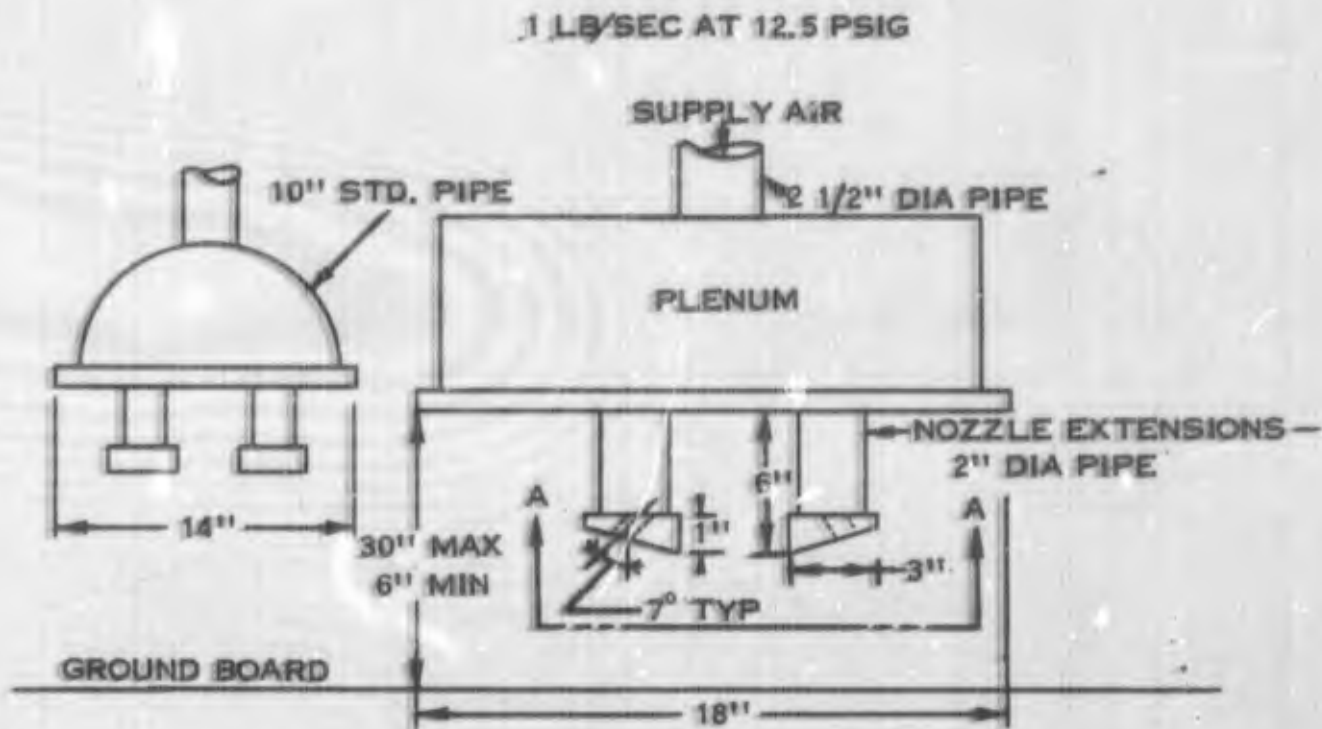


Figure 122. Model Nozzle Arrangement for P.1127

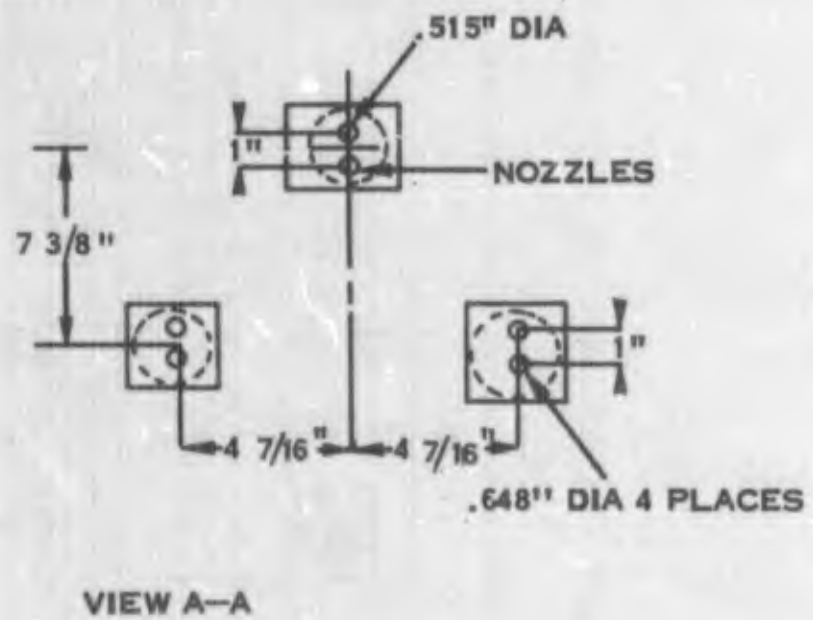
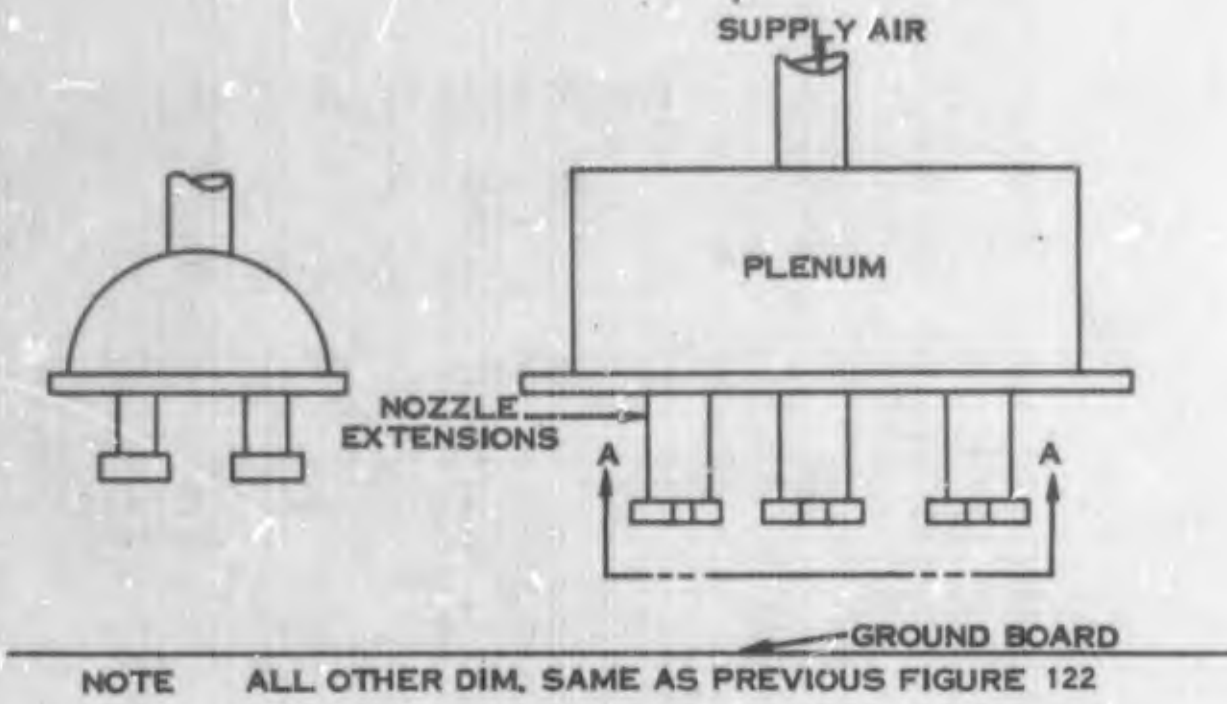


Figure 123. Model Nozzle Arrangement for VJ101

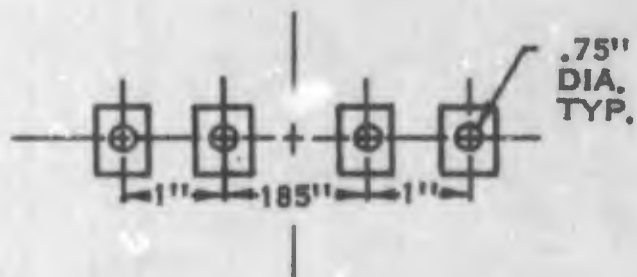
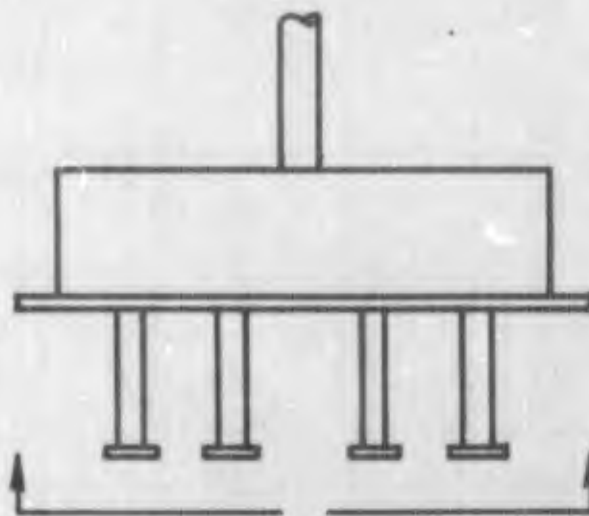


Figure 124. Model Nozzle Arrangement for XC-142

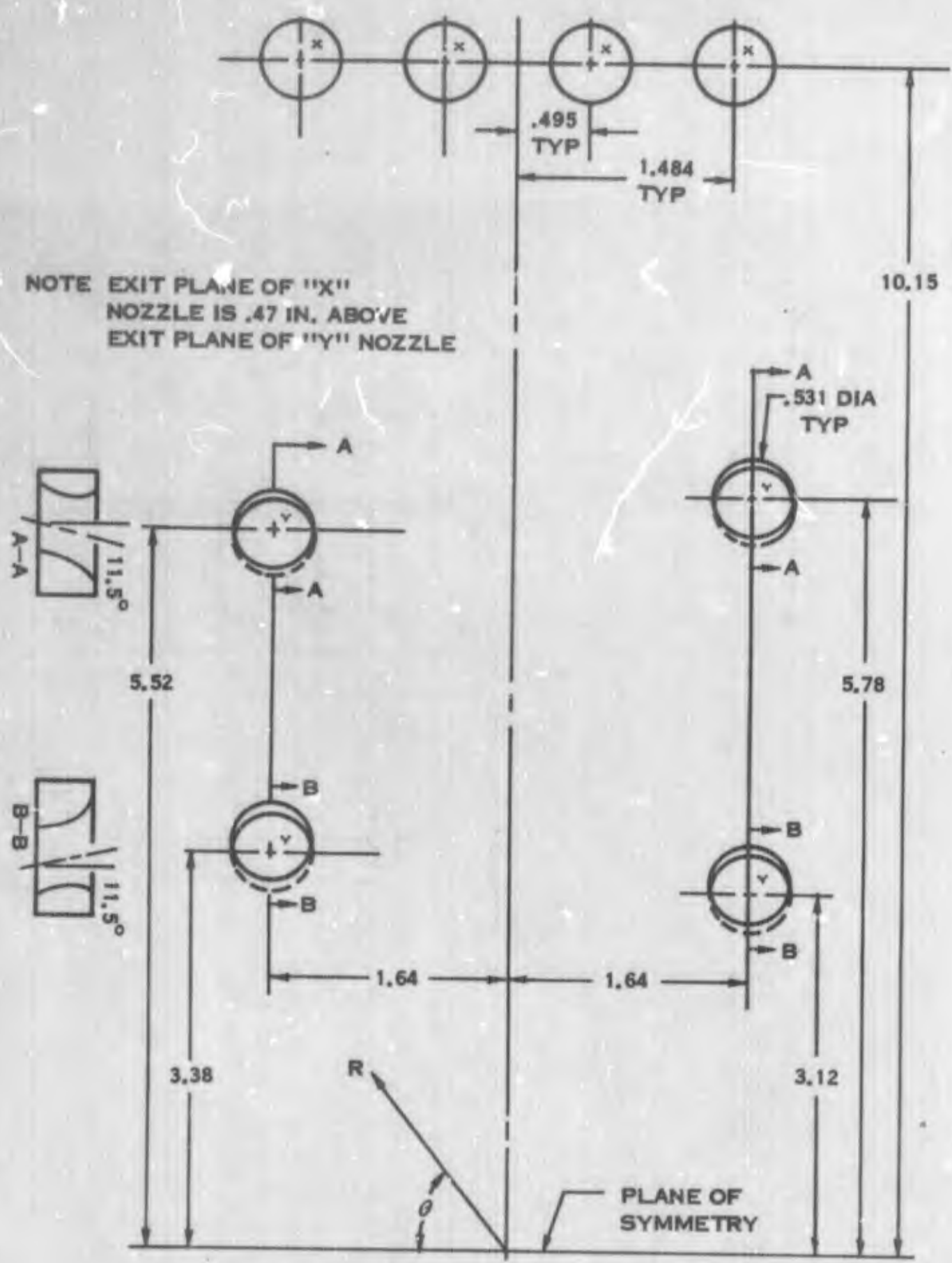


Figure 125. Model Nozzle Arrangement for DO-31

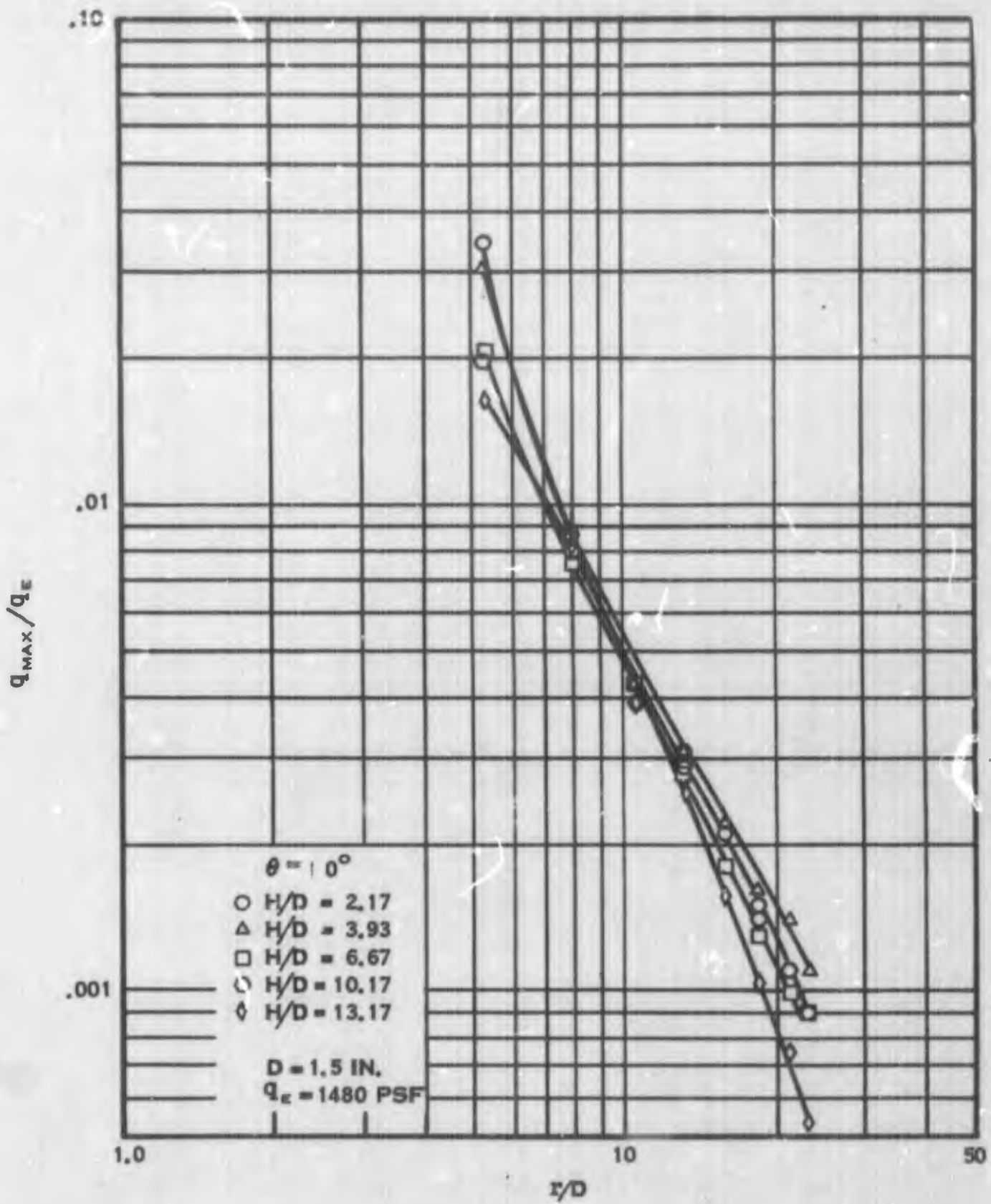


Figure 126. P.1127 Model Downwash Data From the University of Texas (a)

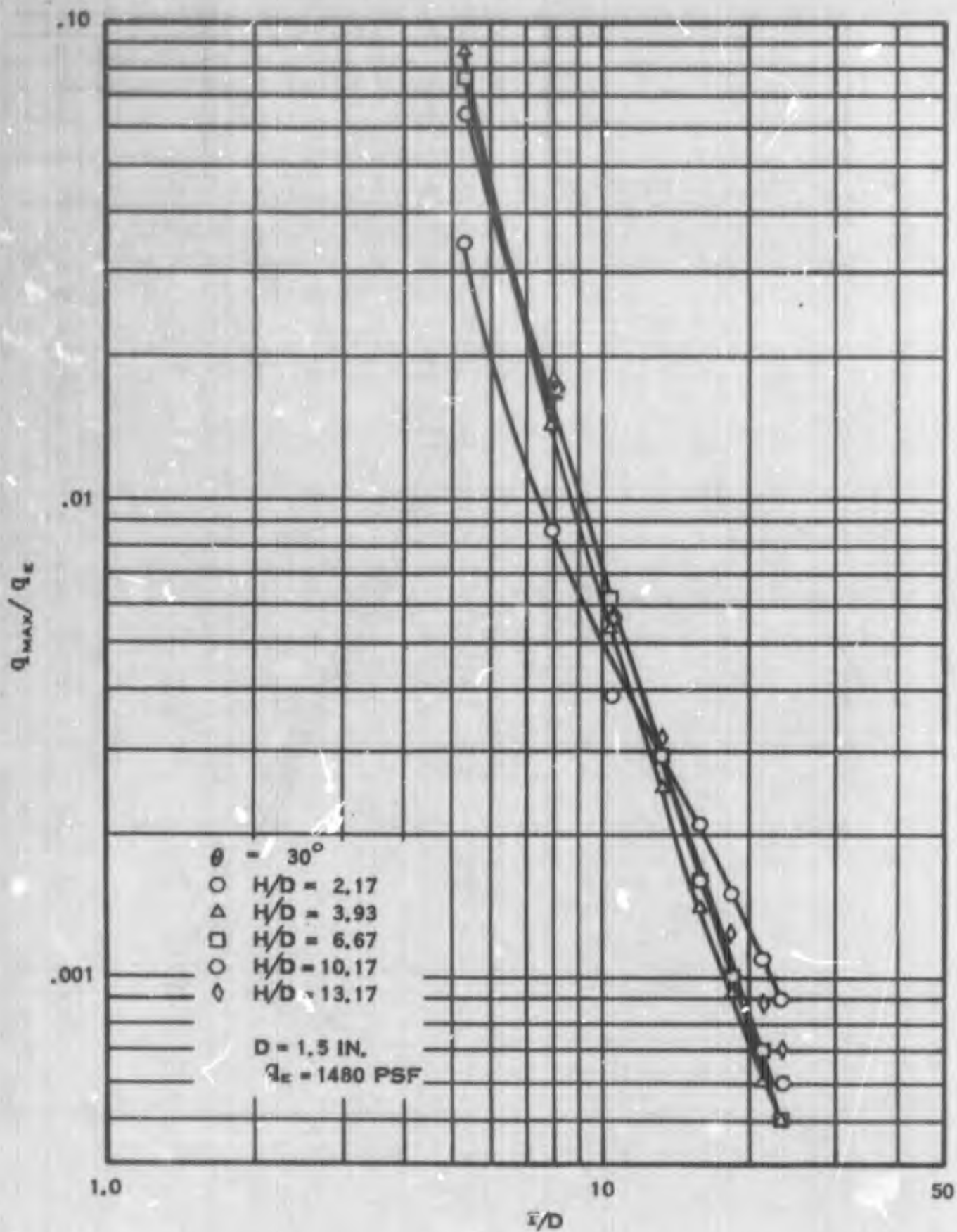


Figure 126. P.1127 Model Downwash Data From the University of Texas (Continued) (b)

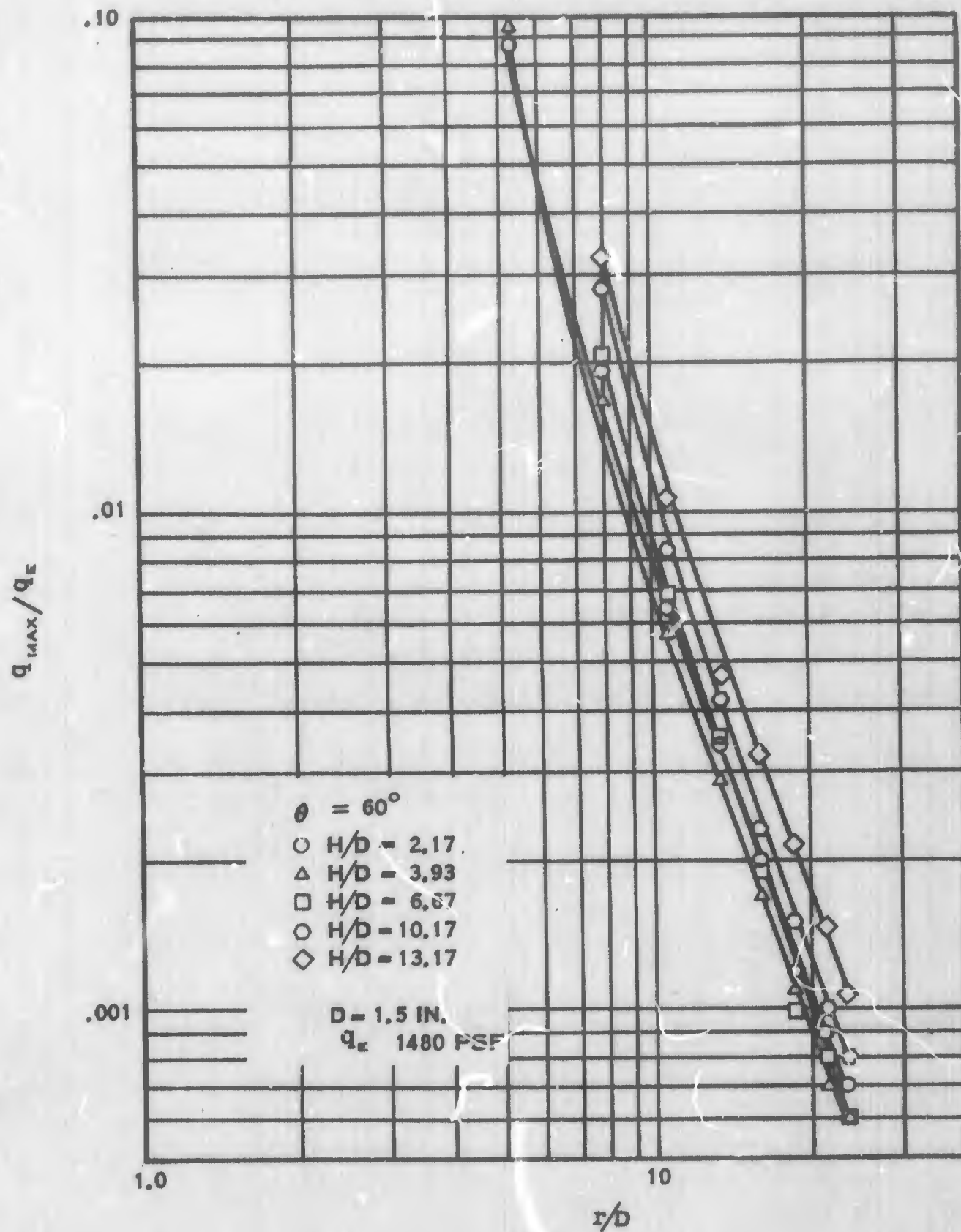


Figure 126. P.1127 Model Downwash Data From the University of Texas (Continued) (c)

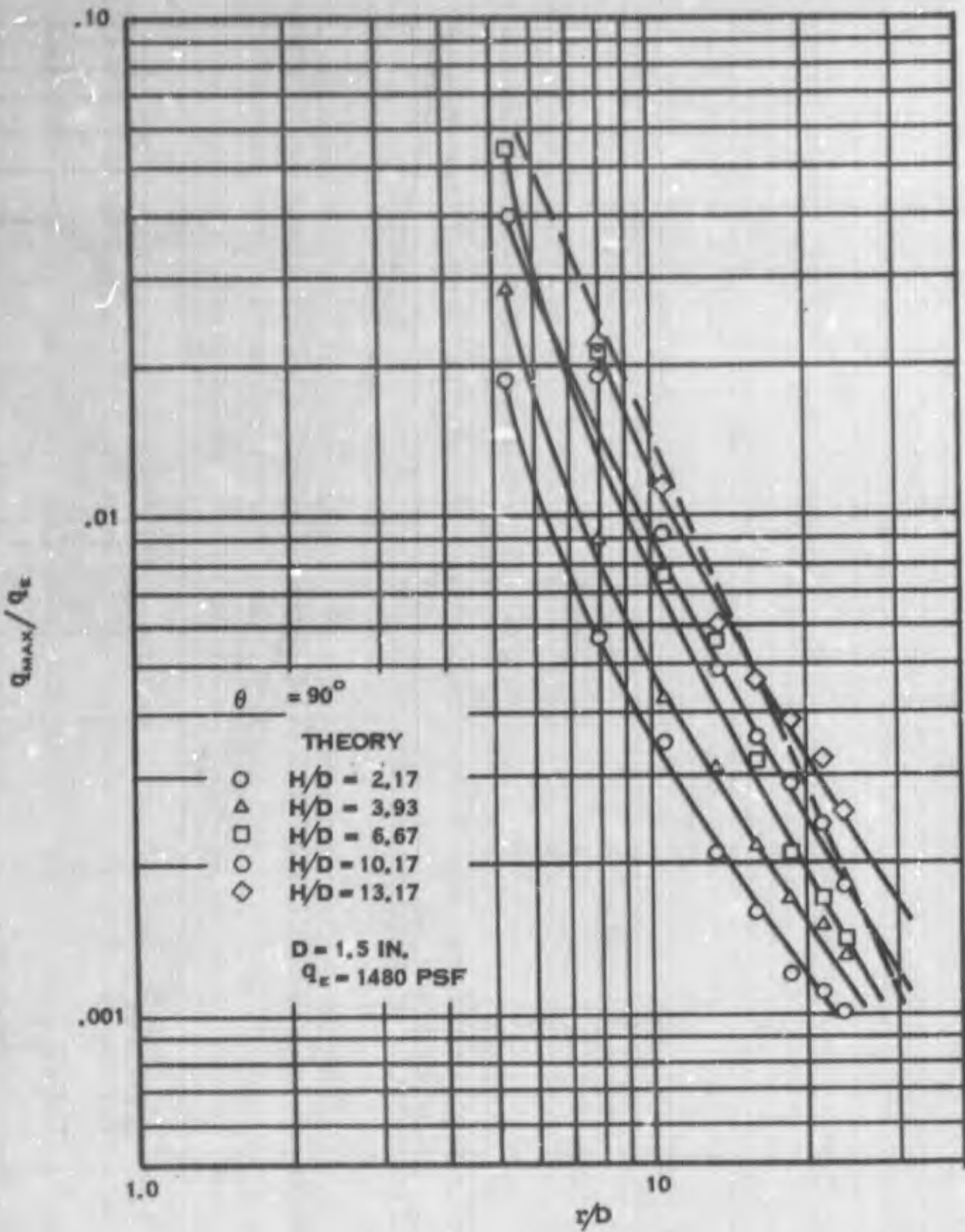


Figure 126. P<sub>1127</sub> Model Downwash Data From the University of Texas (Continued) (d)

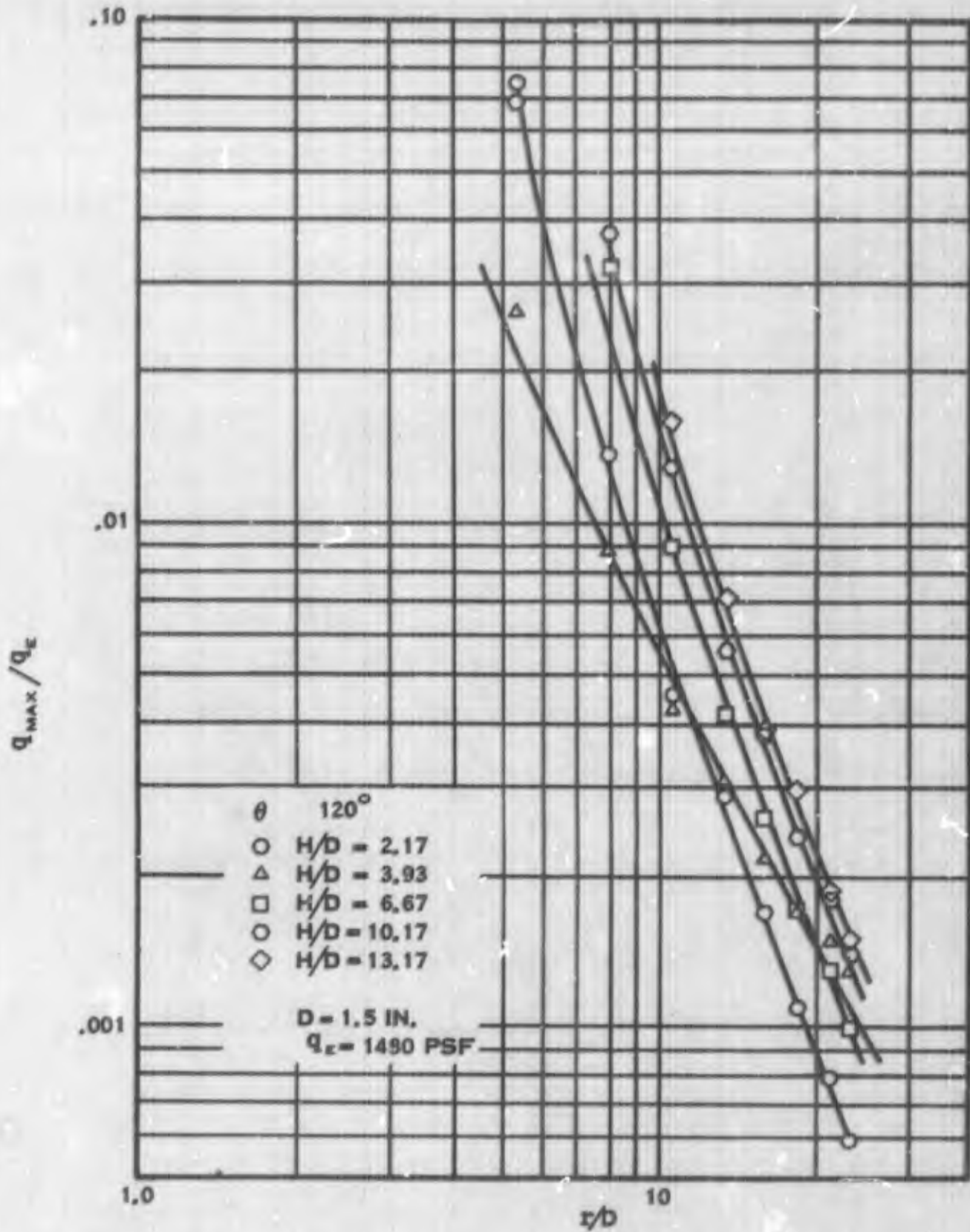


Figure 126. P.1127 Model Downwash Data From the University of Texas (Continued) (e)

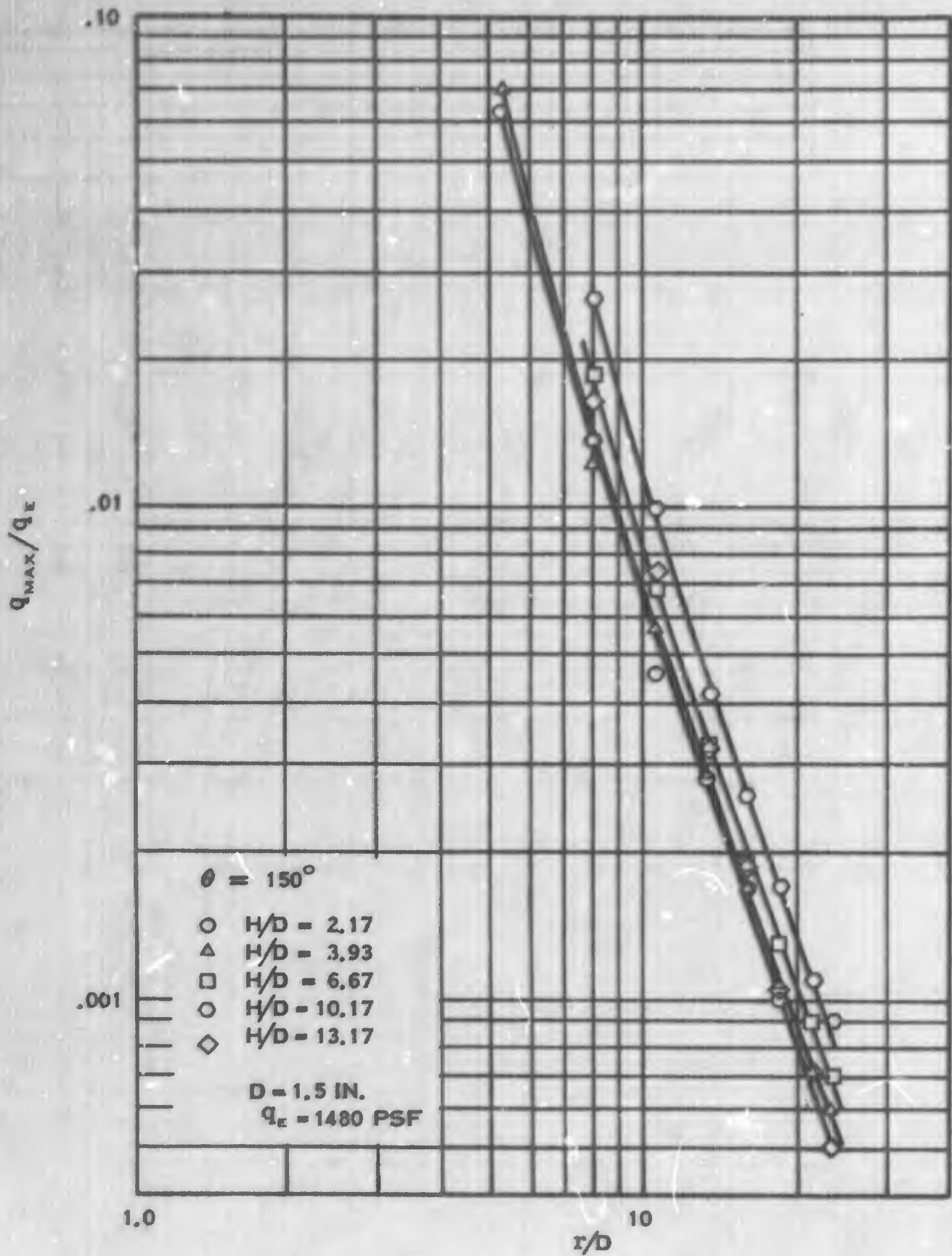


Figure 126. P.1127 Model Downwash Data From the University of Texas (Continued) (f)

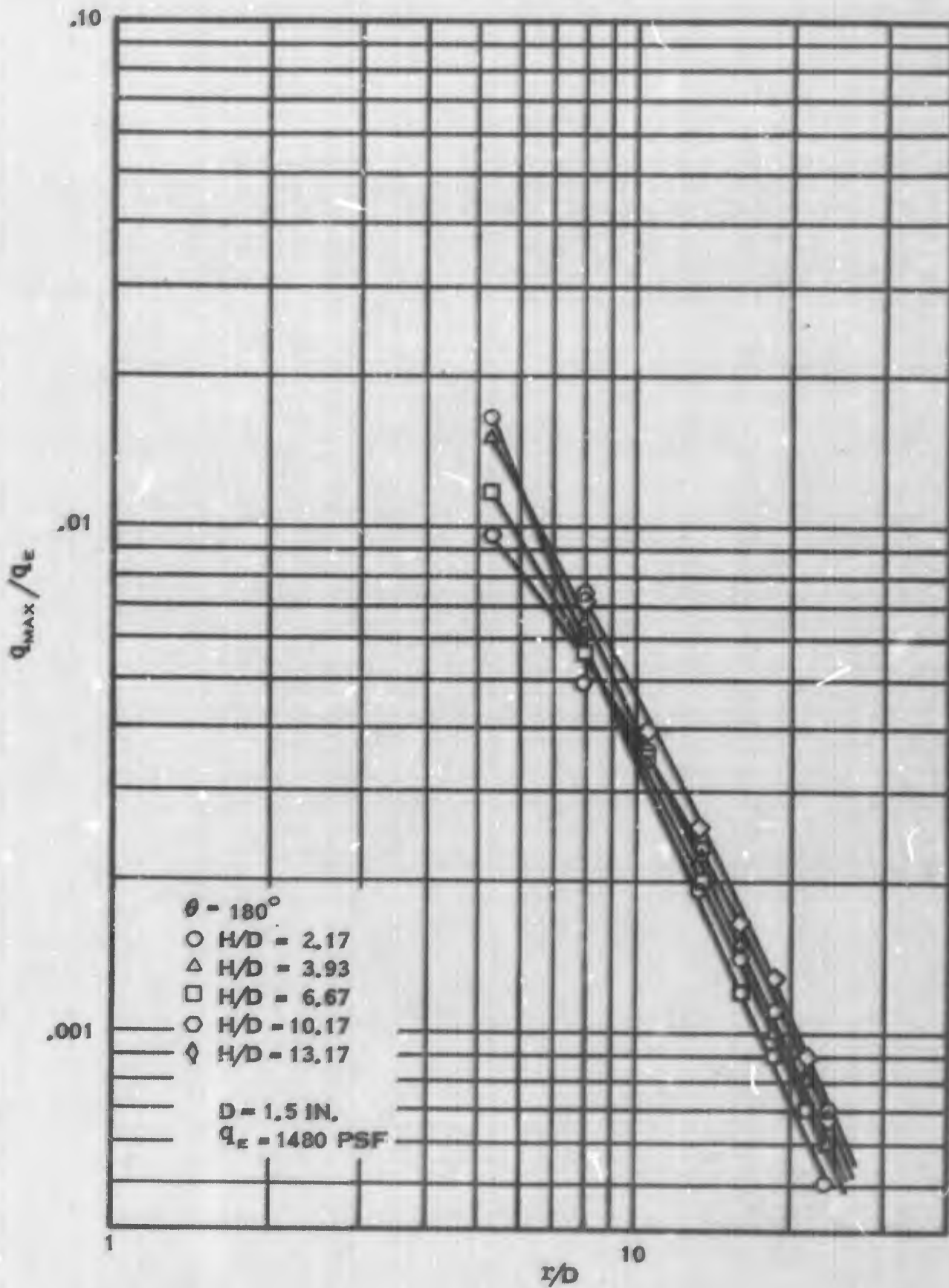


Figure 126. F.1127 Model Downwash Data From the University of Texas (Concluded) (g)



Figure 127. Lines of Constant  $q_{max}/q_e$  for P.1127 Model

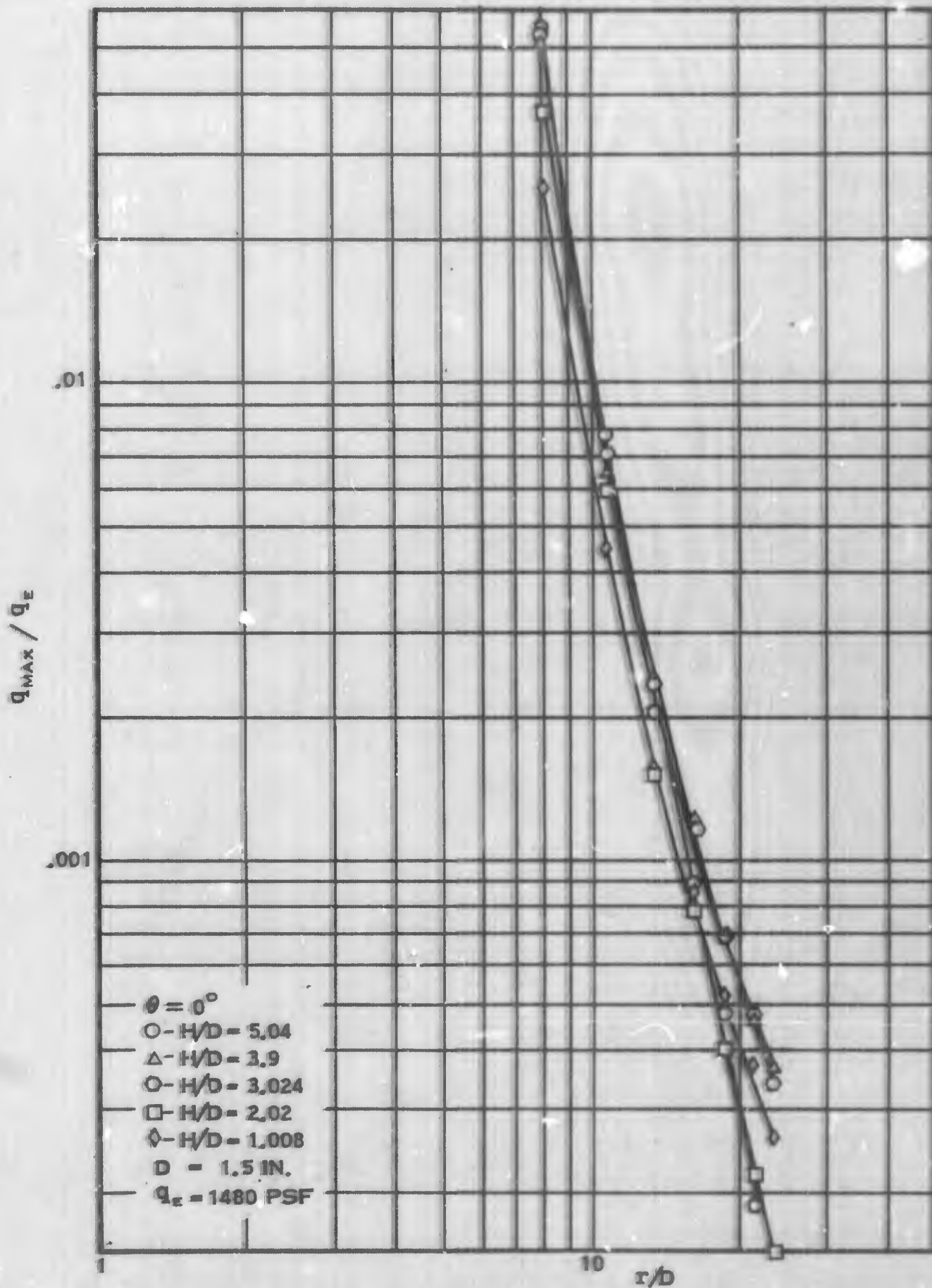


Figure 128. VJ101 Model Downwash Data From the University of Texas (a)

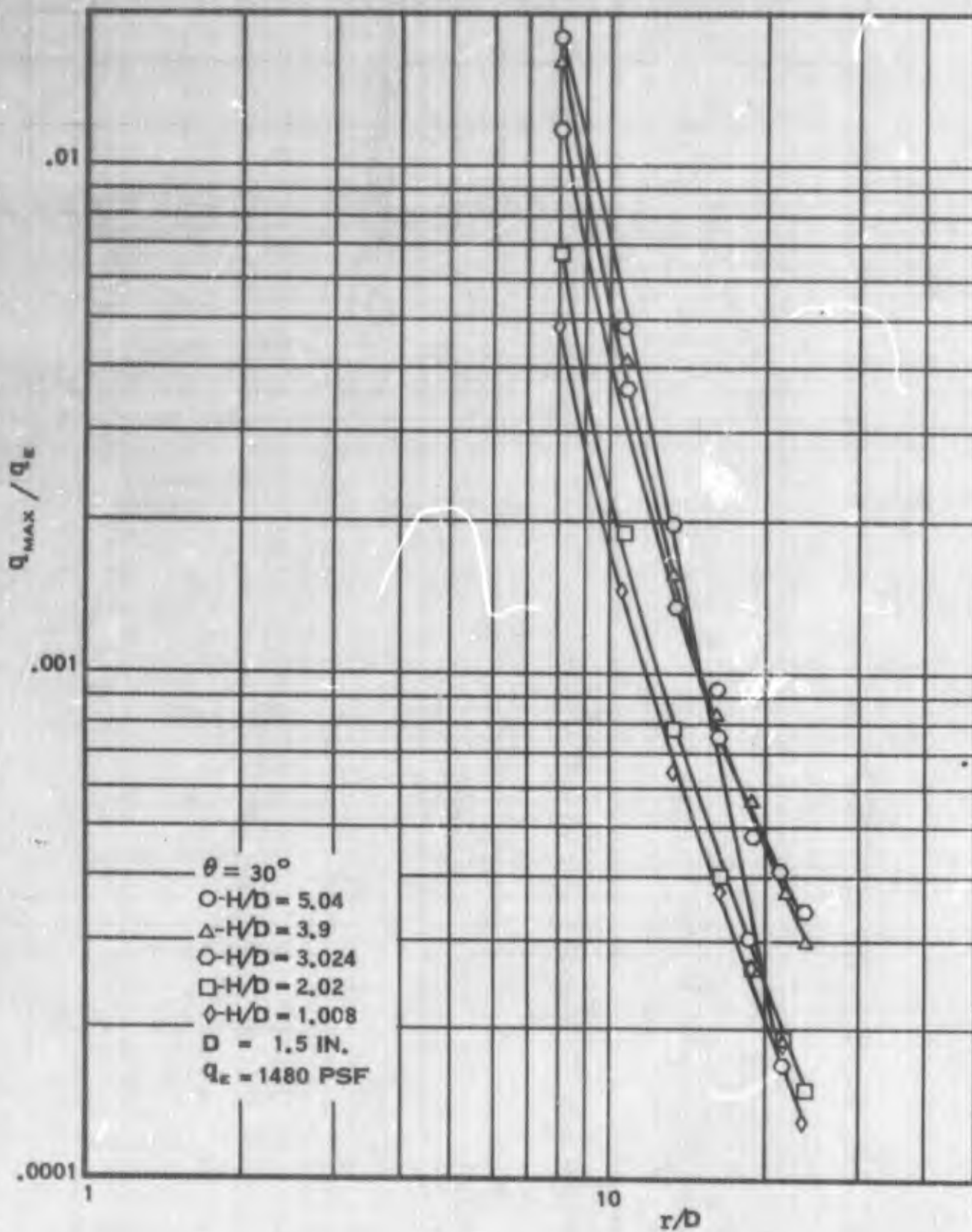


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (b)

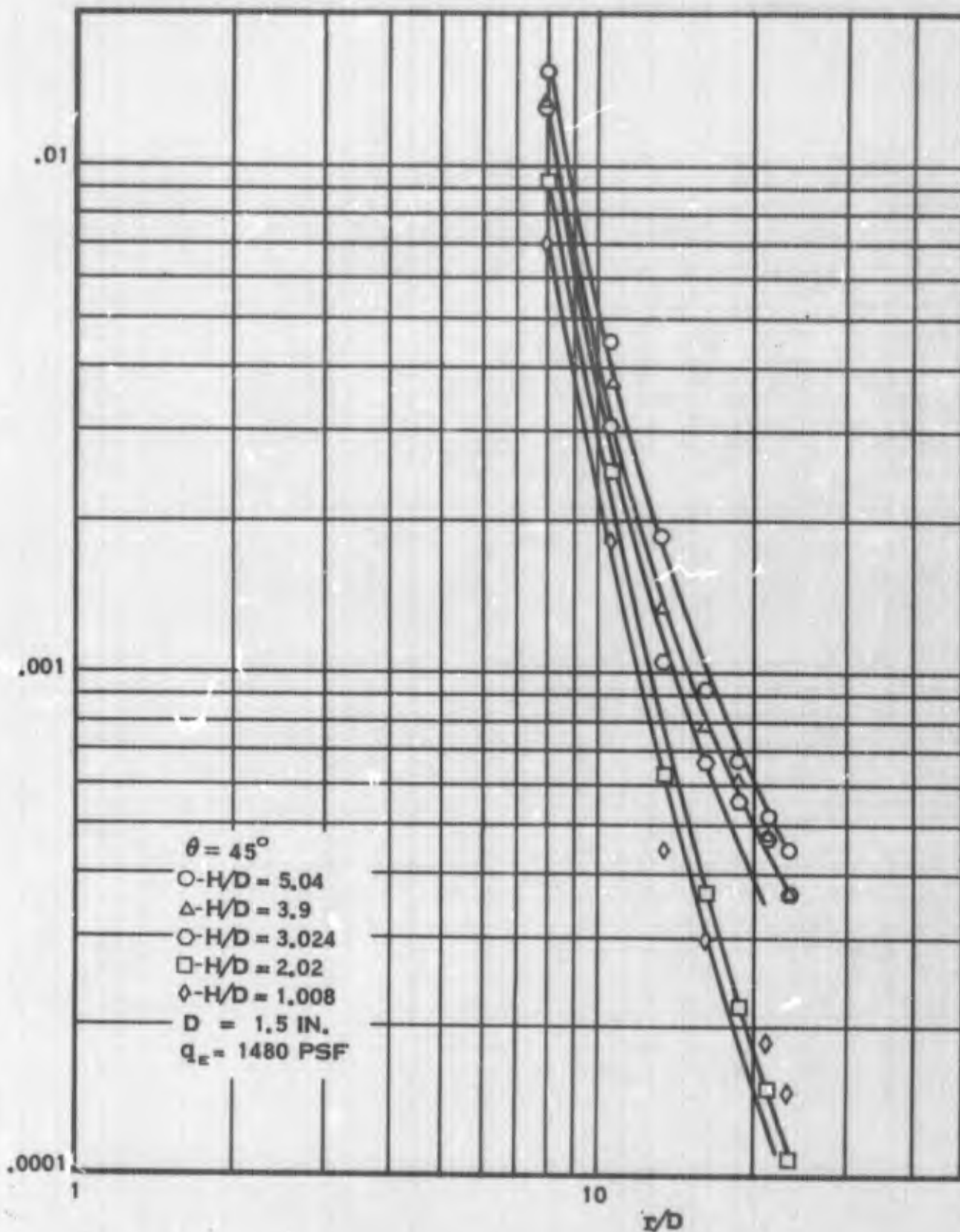


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (c)

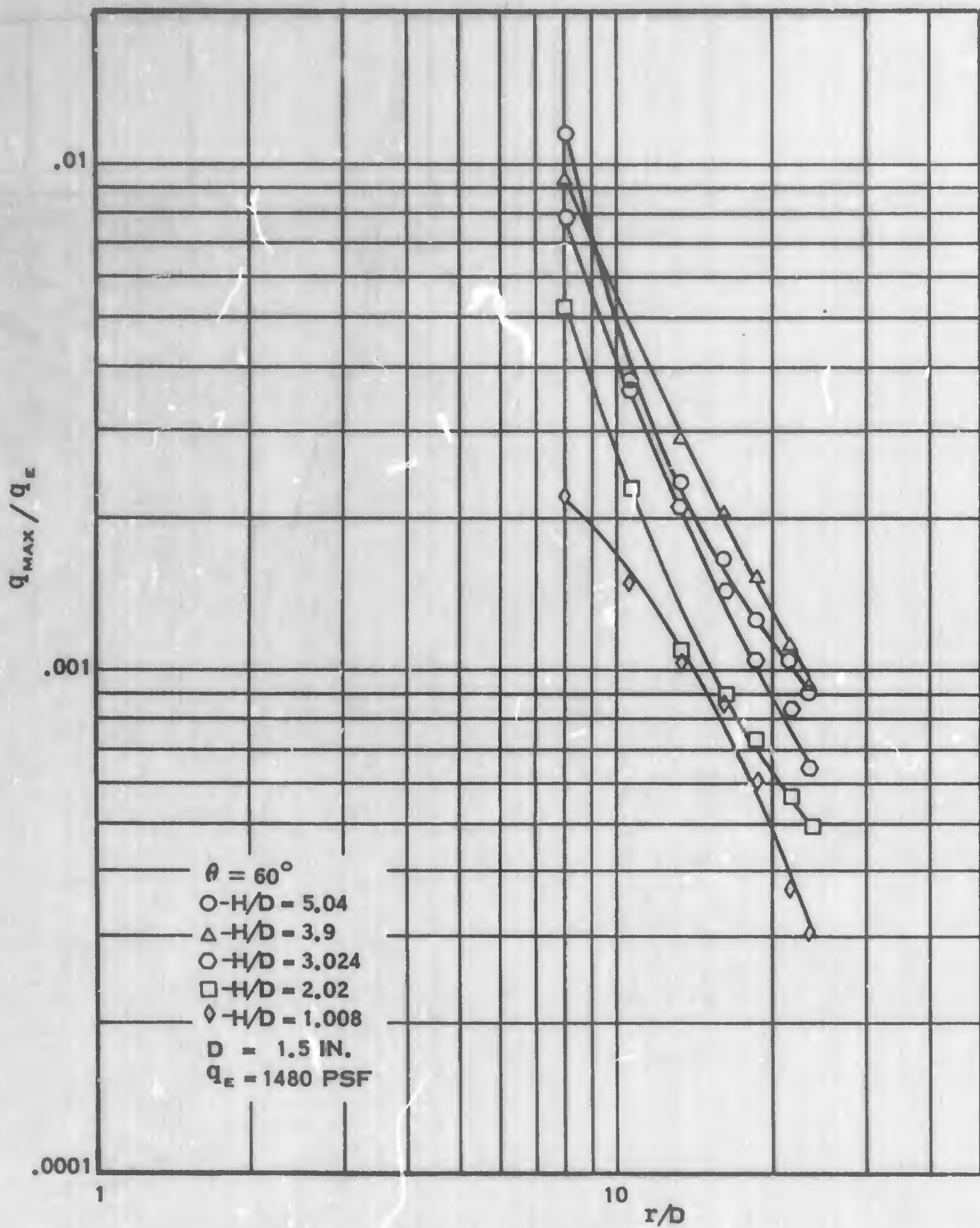


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (d)

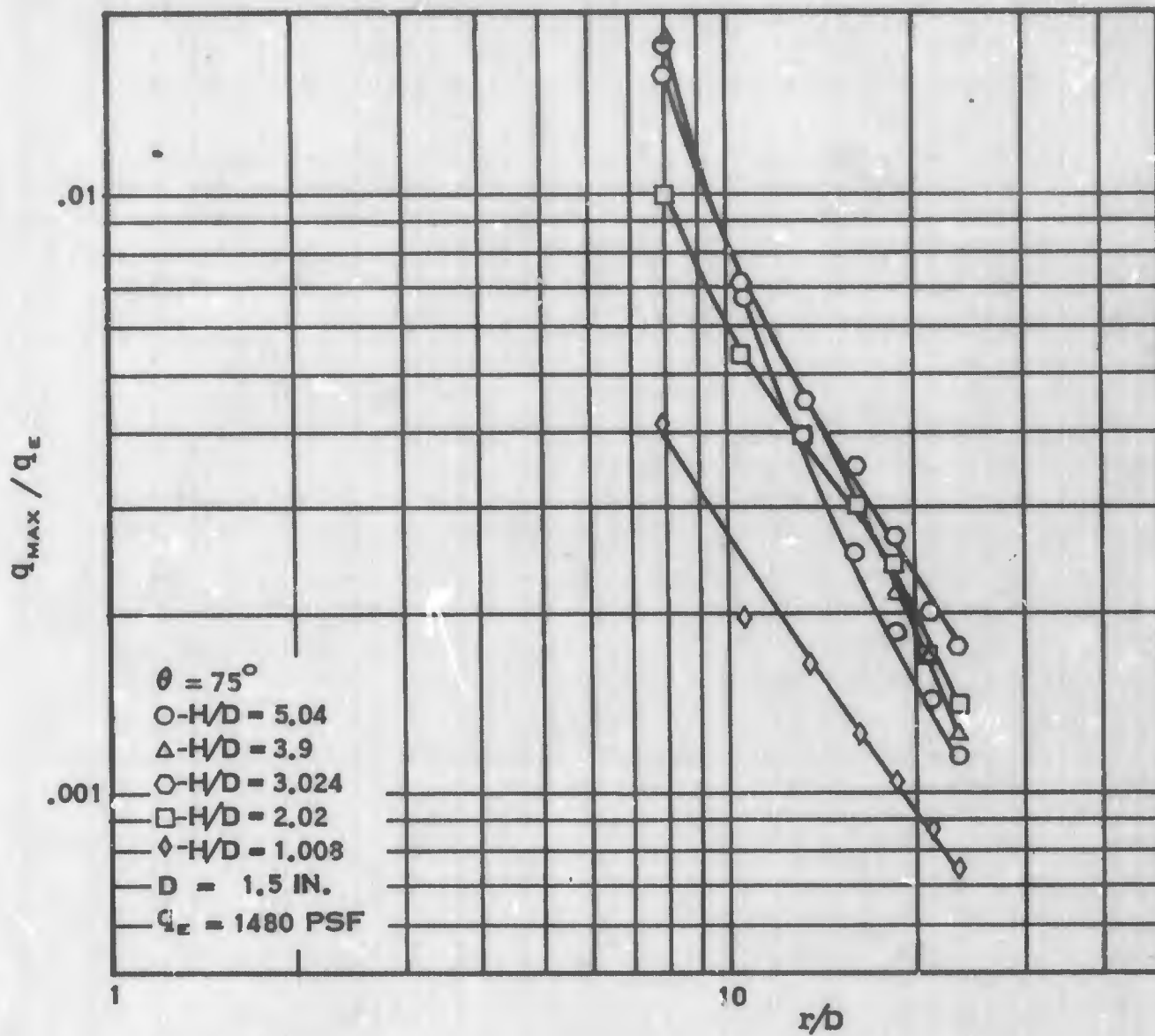


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (e)

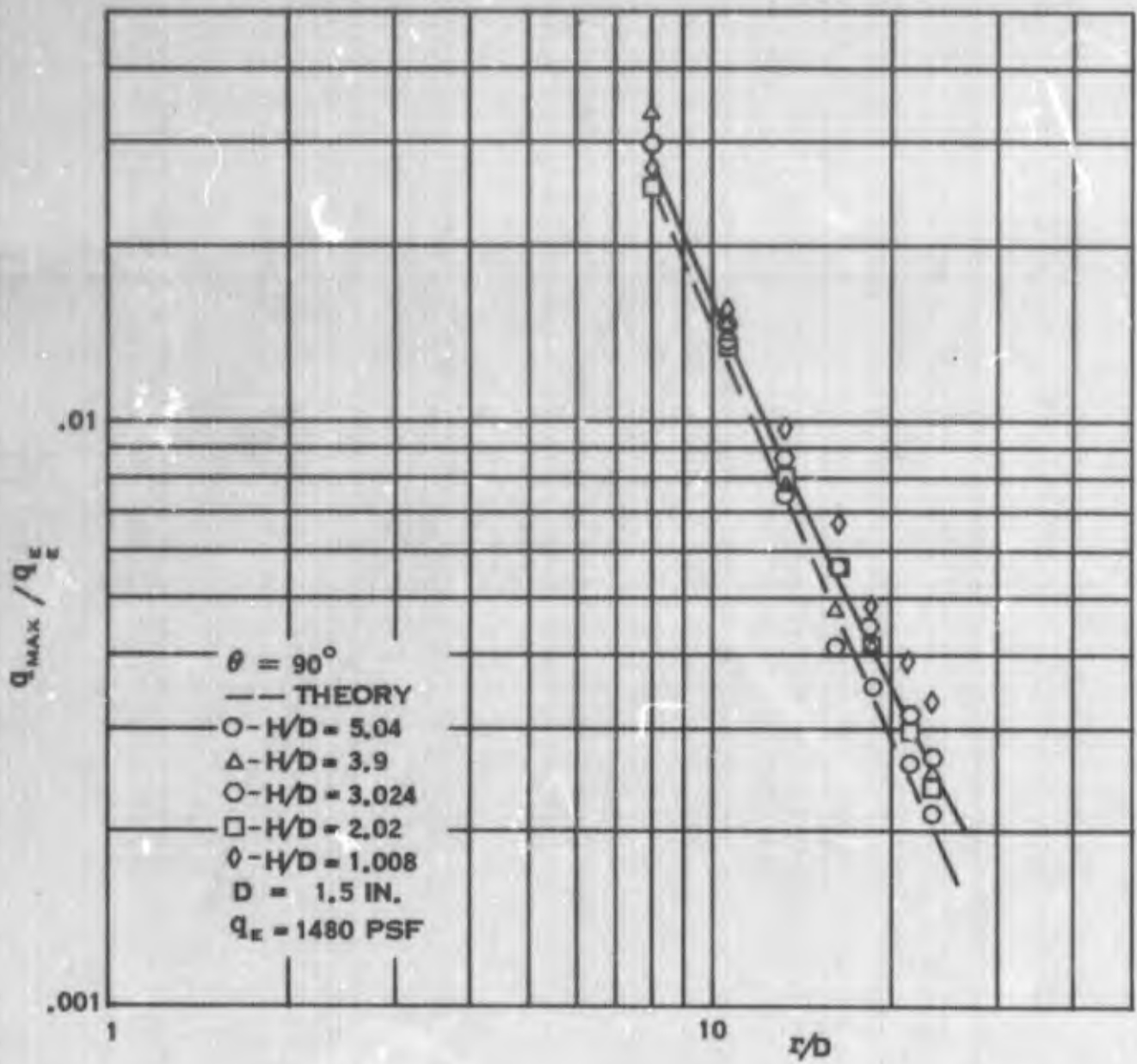


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (f)

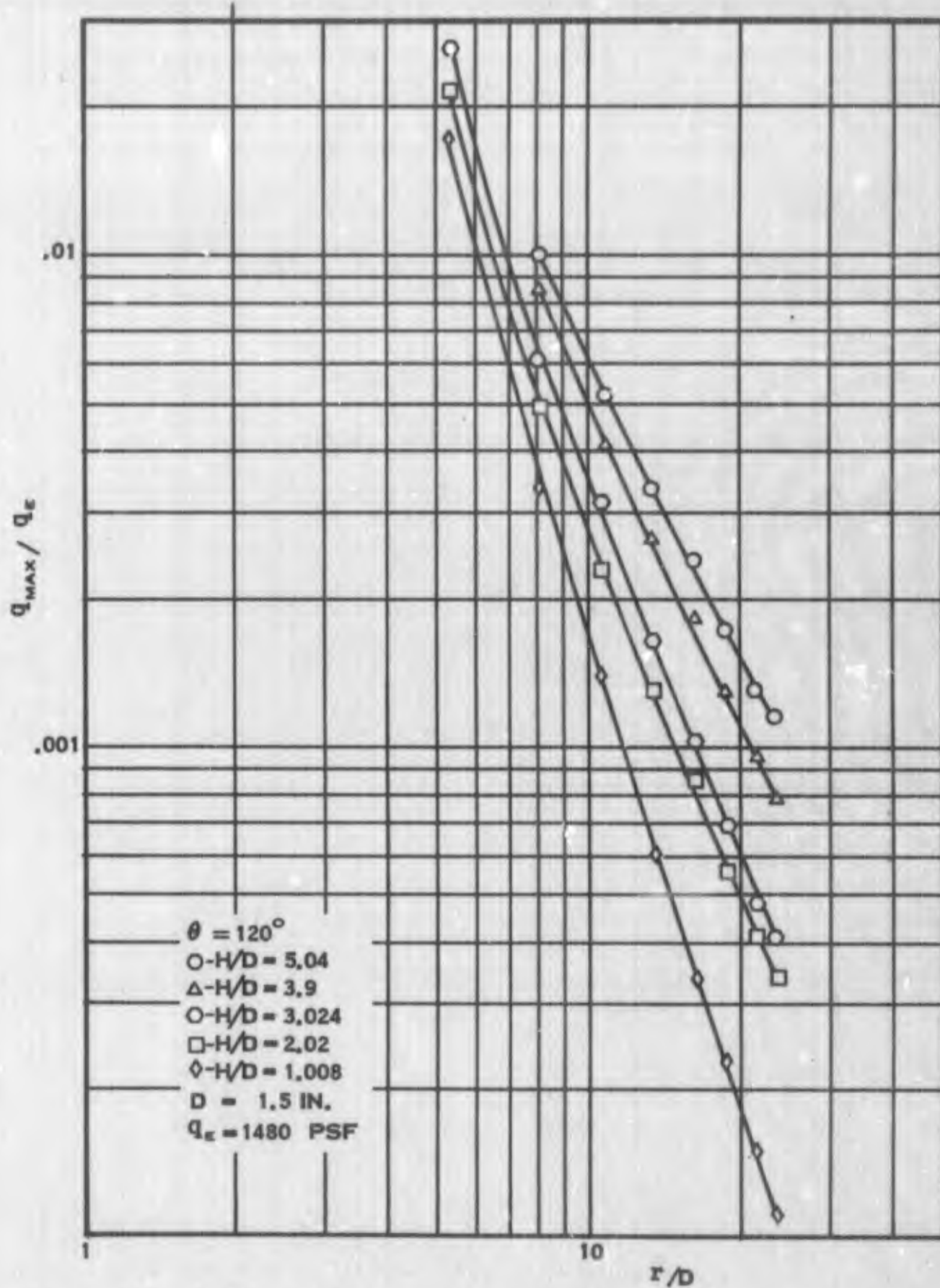


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (g)

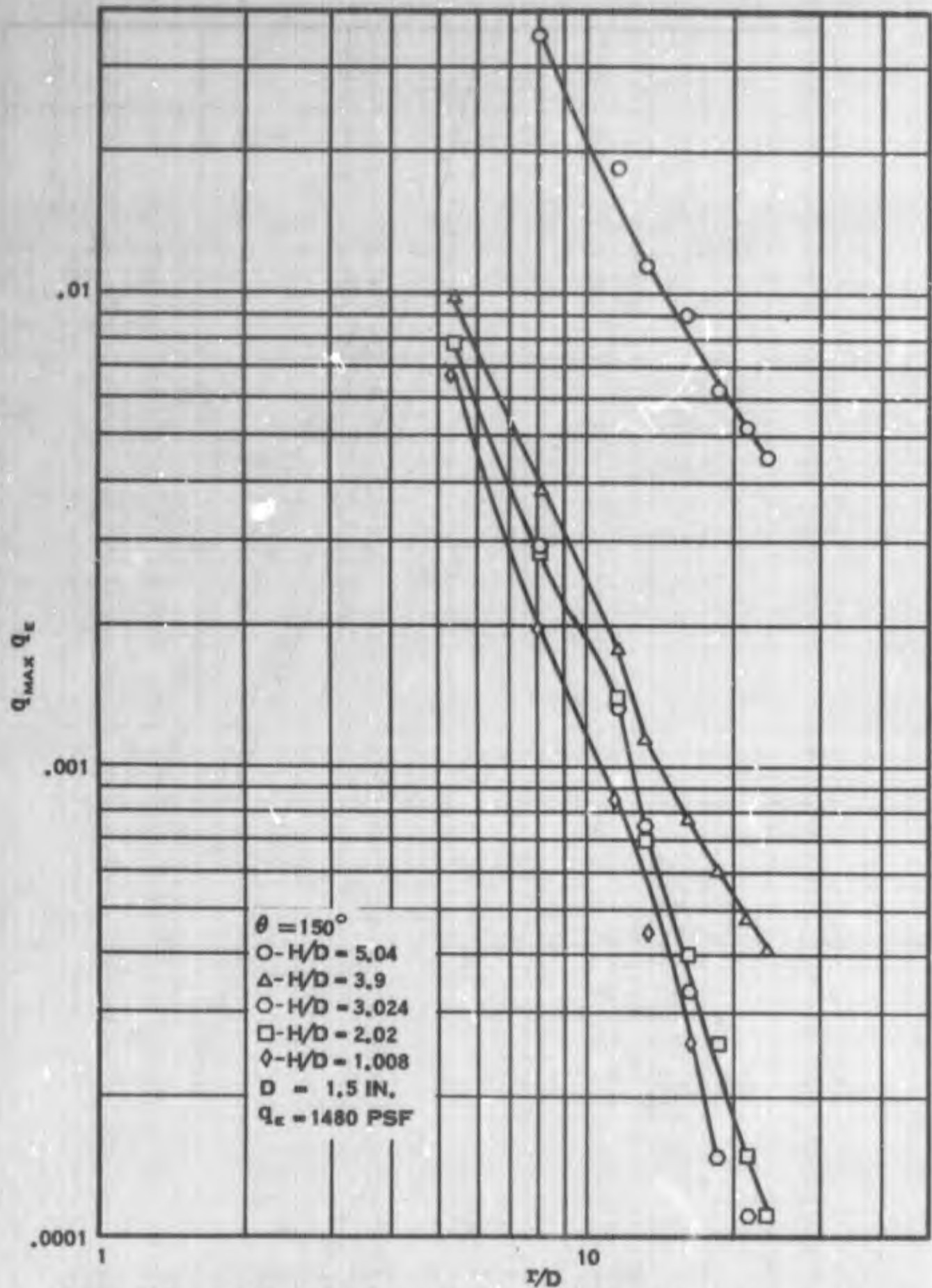


Figure 128. VJ101 Model Downwash Data From the University of Texas (Continued) (h)

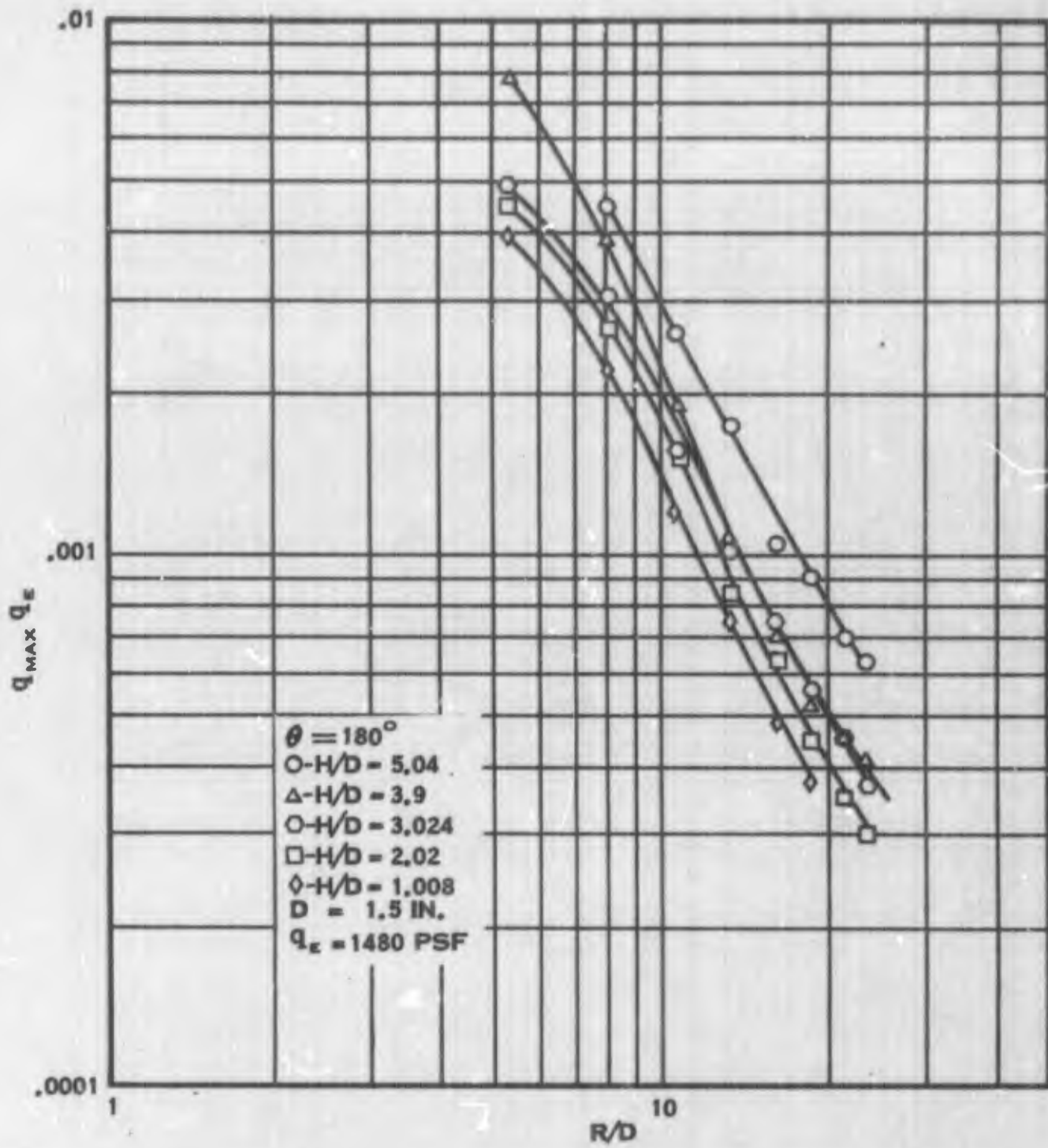
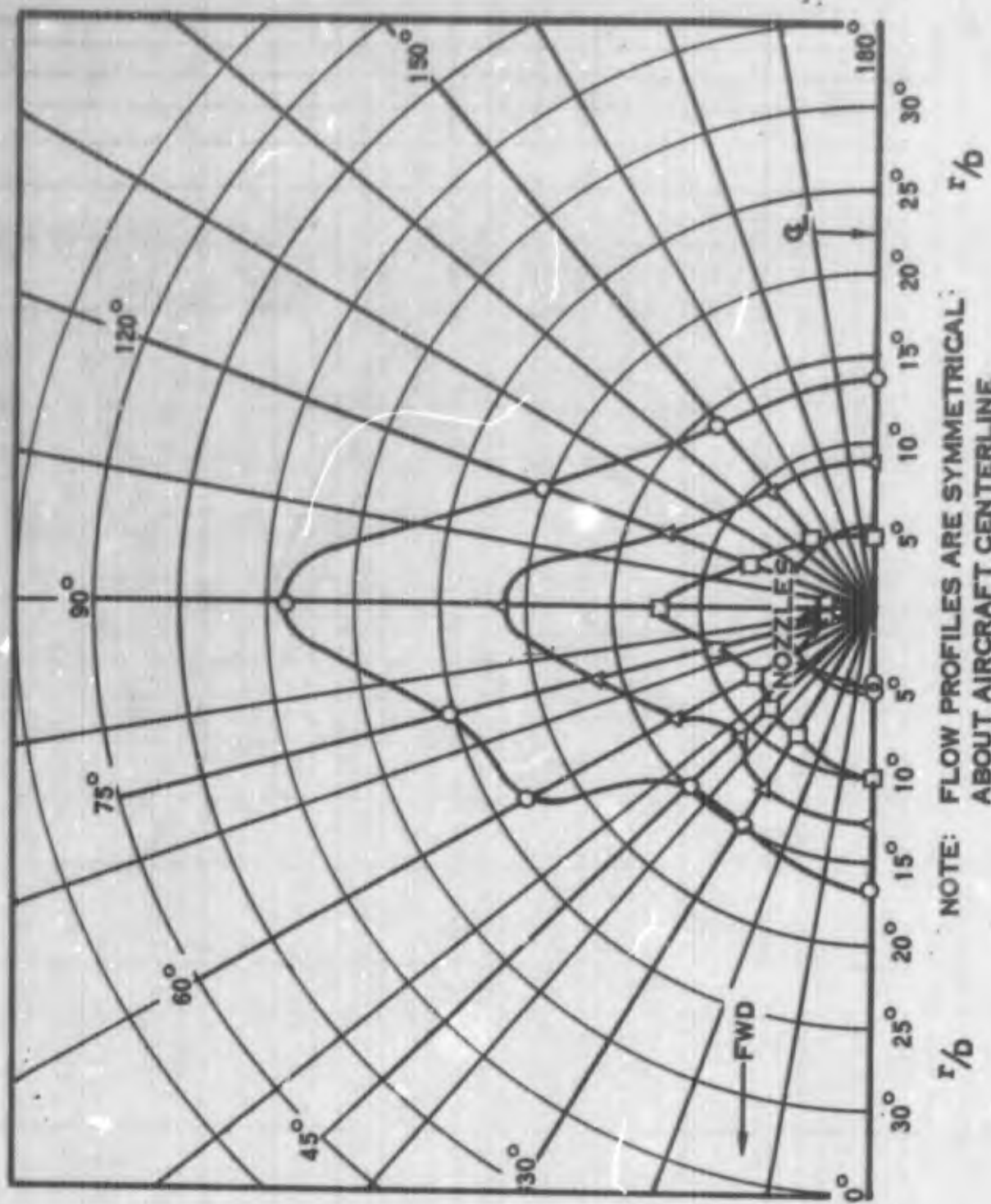


Figure 128. VJ101 Model Downwash Data From the University of Texas (Concluded) (i)



$H/D = 3.9$   
 $\circ - q_{MAX} / q_E = .001$   
 $\Delta - q_{MAX} / q_E = .003$   
 $\square - q_{MAX} / q_E = .01$

$D = 1.5 \text{ IN.}$   
 $q_E = 1480 \text{ PSF}$

$r/d$        $r/d$   
 NOTE: FLOW PROFILES ARE SYMMETRICAL ABOUT AIRCRAFT CENTERLINE

Figure 129. Lines of Constant  $q_{max}/q_0$  for VJ101 Model

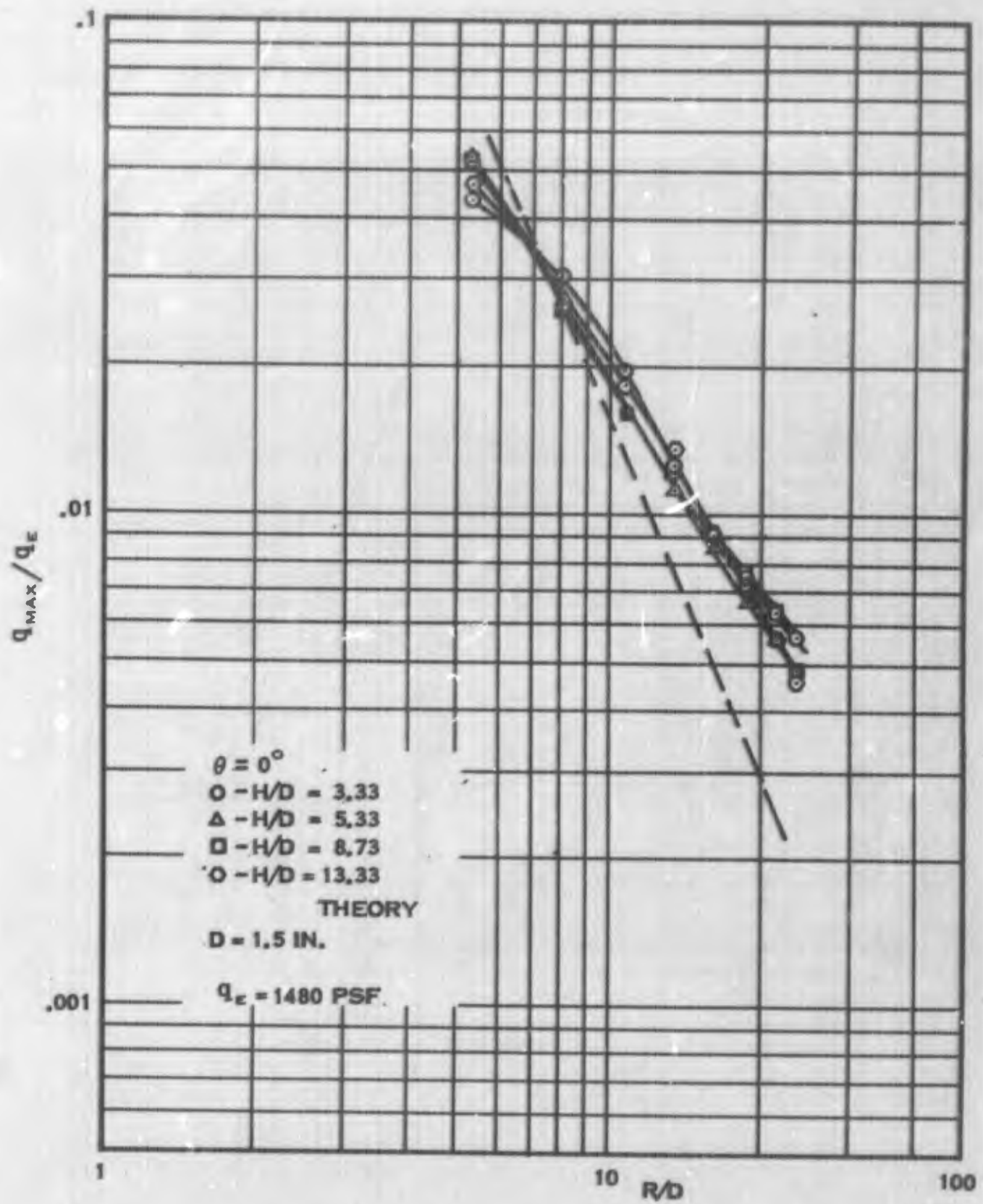


Figure 130. XC-142 Model Downwash Data From the University of Texas (a)

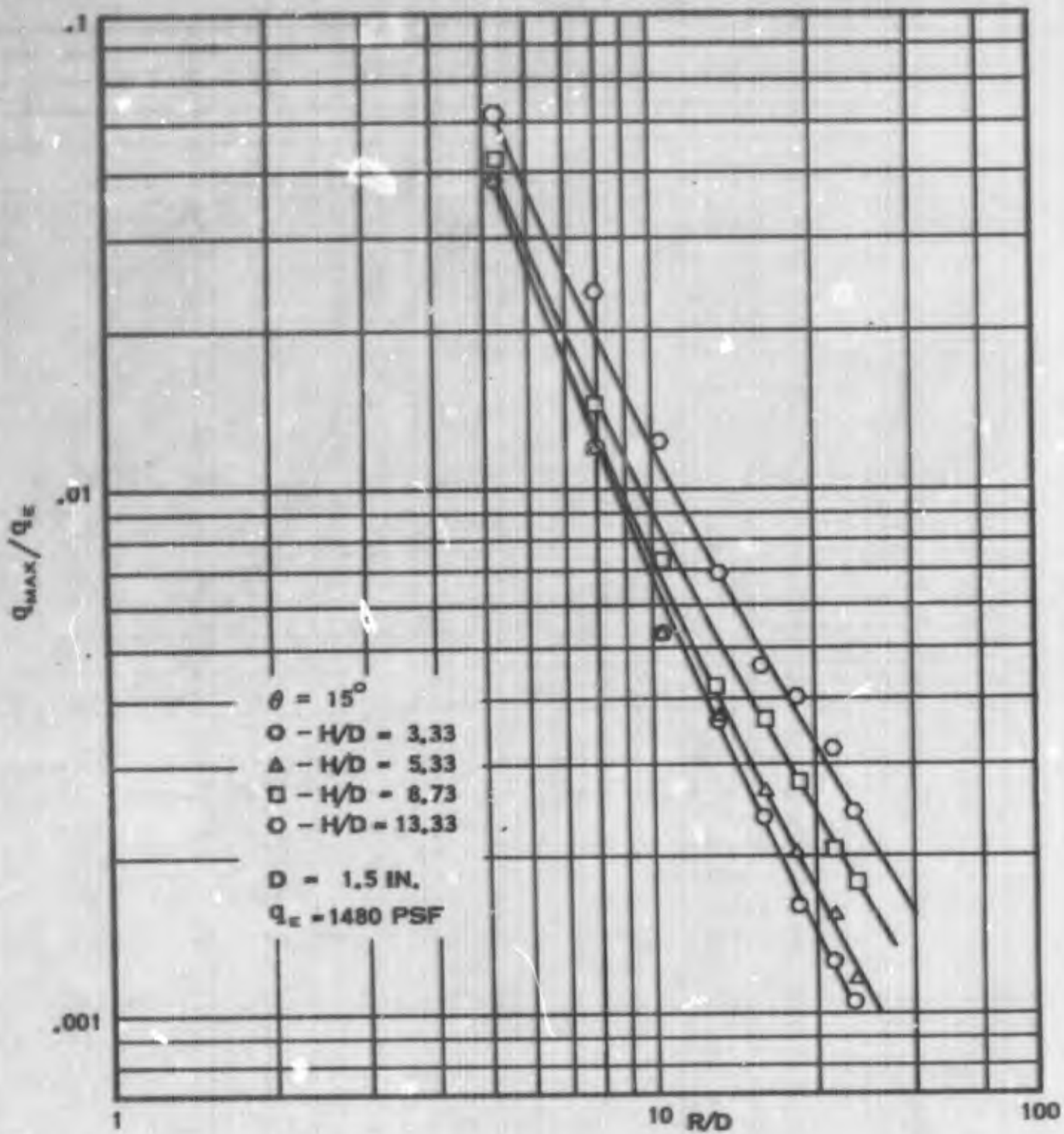


Figure 130. XC-142 Model Downwash Data From the University of Texas (Continued) (b)

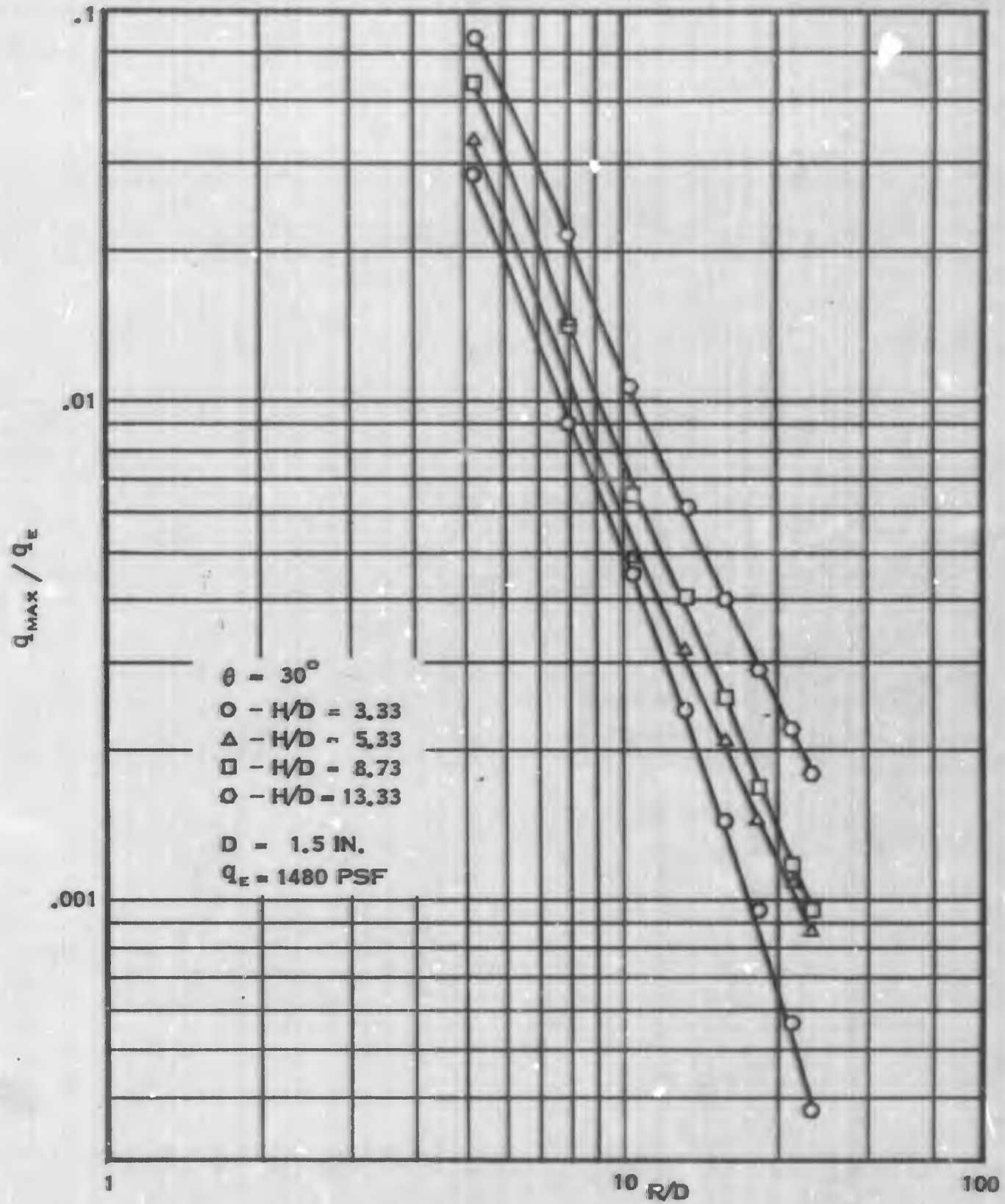


Figure 130. XC-142 Model Downwash Data From the University of Texas (Continued) (c)

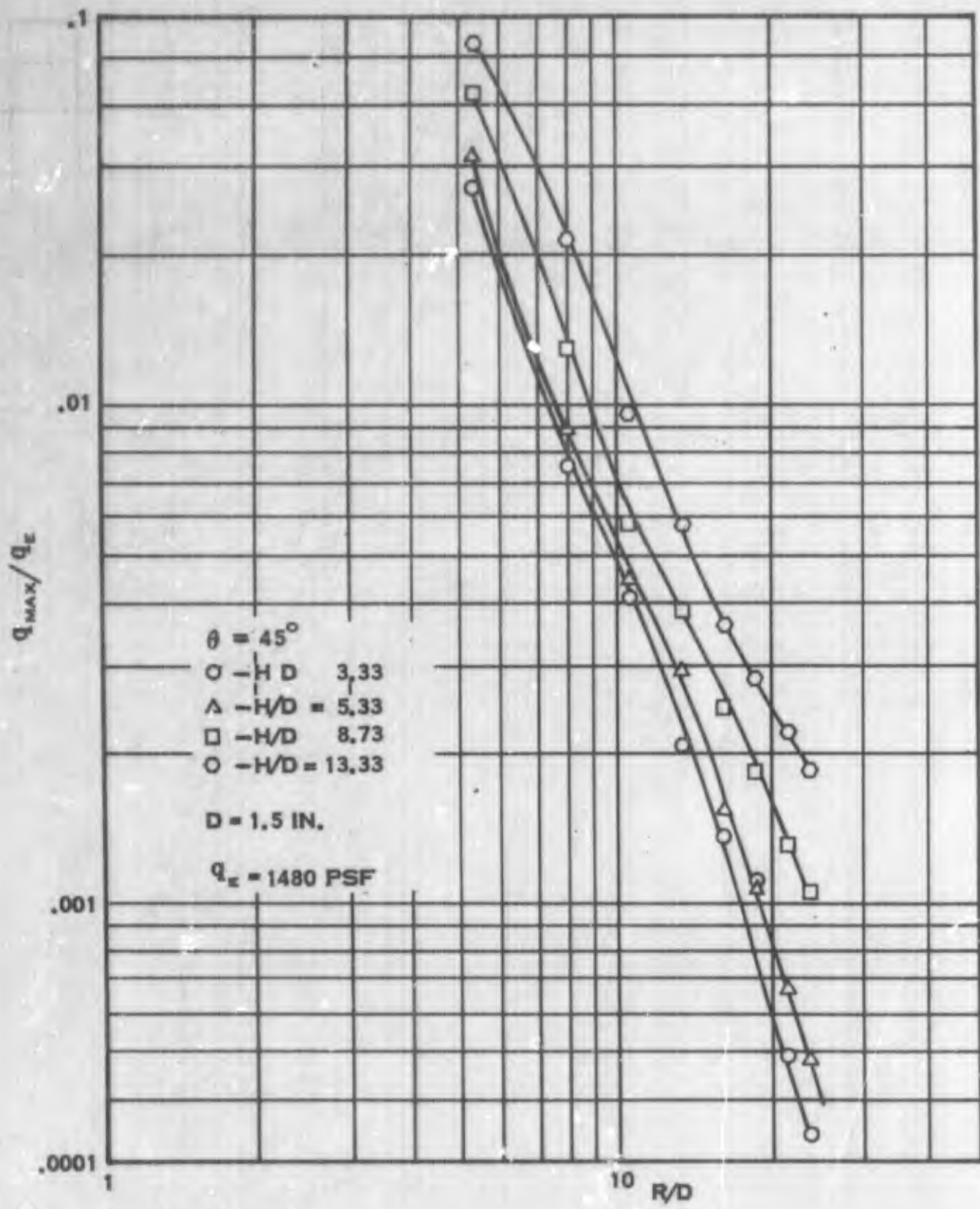


Figure 130. XC-142 Model Downwash Data From the University of Texas (Continued) (d)

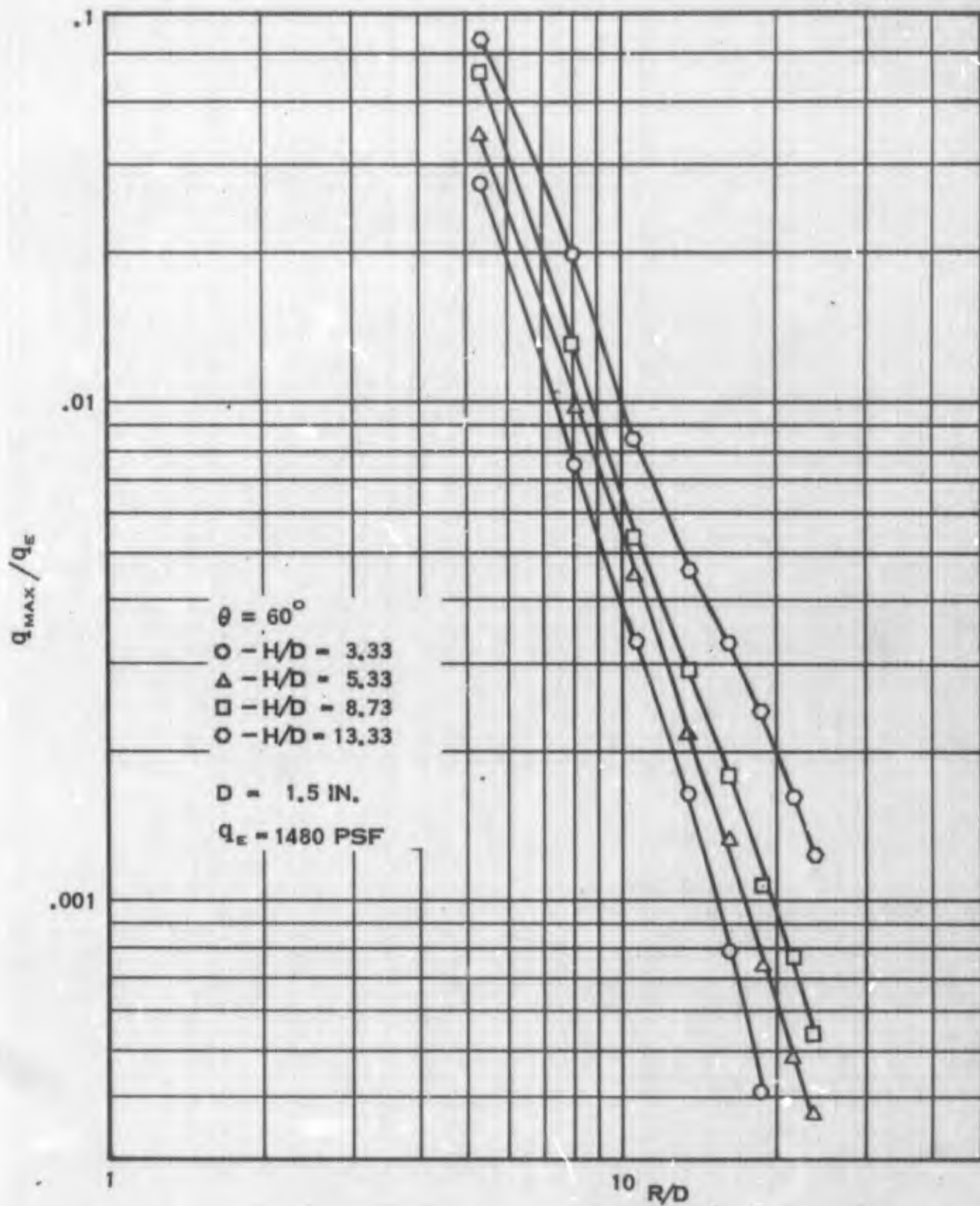


Figure 130. XC-142 Model Downwash Data From the University of Texas (Continued) (e)

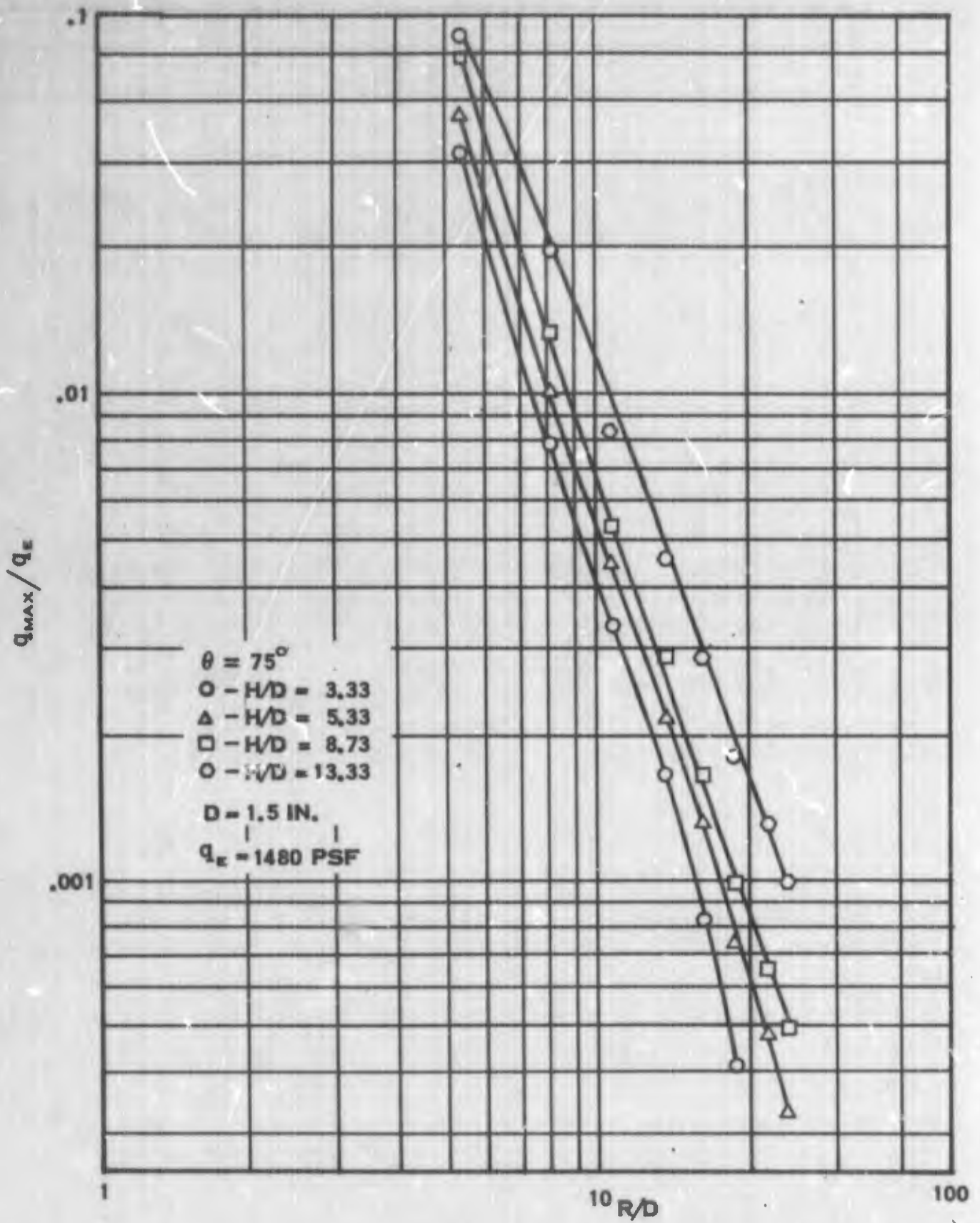


Figure 130. XC-142 Model Downwash Data From the University of Texas (Continued) (f)

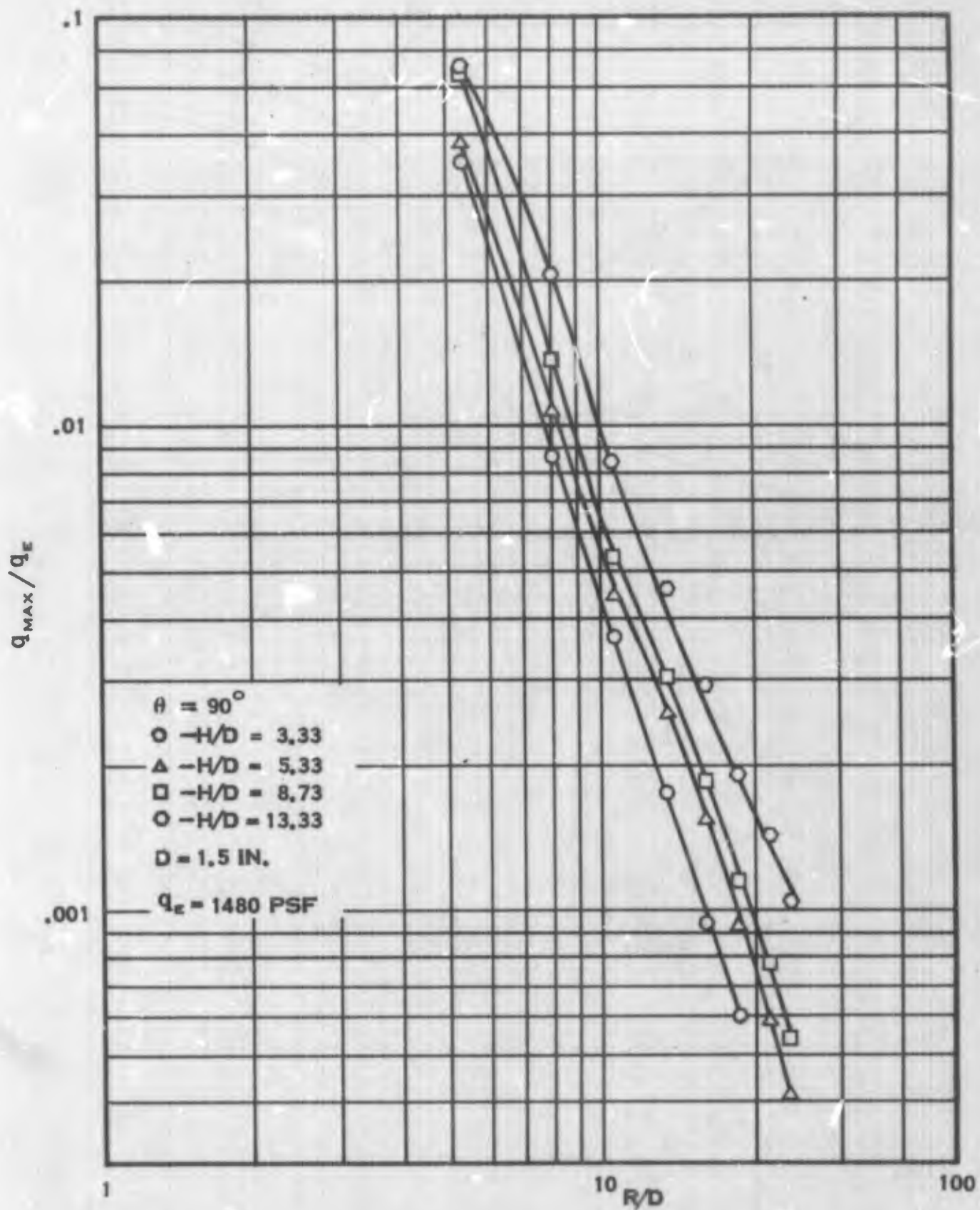


Figure 130. XC-142 Model Downwash Data From the University of Texas (Concluded) (g)

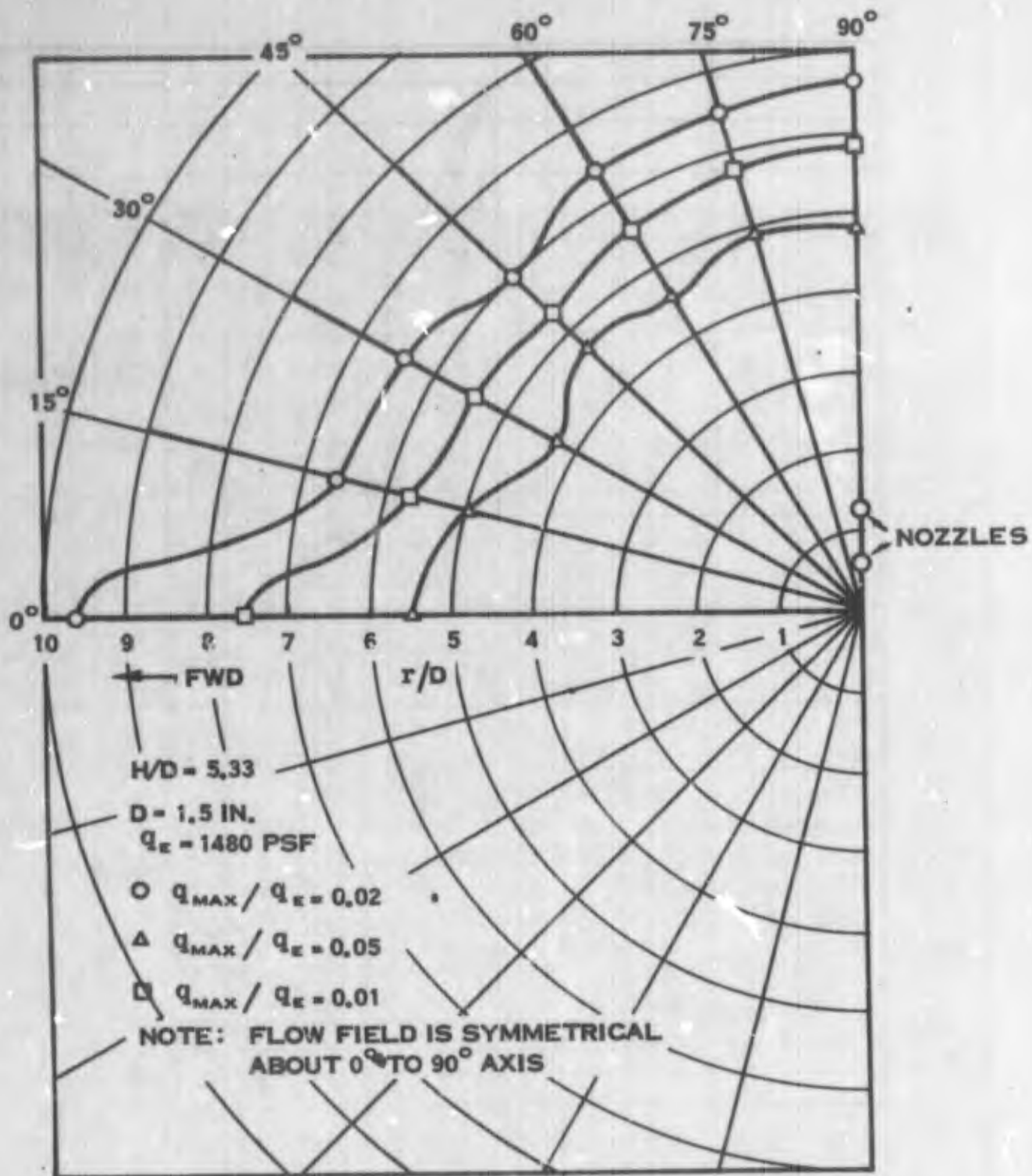


Figure 131. Lines of Constant  $q_{MAX}/q_E$  for XC-142 Model

the edge of the rapid site pad, the corresponding  $q_{max}/q_E$  contour would be the shape and absolute minimum pad size required to prevent erosion with no allowances made for landing tolerances. Take for example the P-1127 countour line for  $q_{max}/q_E = .001$  which corresponds to the erosion threshold for dust and dry snow if  $q_E = 1100$  psf. The minimum pad radius, with no allowance for landing tolerances and assuming either no wind or a constant wind direction, would be  $29D$  or  $84$  feet. Since  $D = 2.91$  feet for the P-1127, the required pad diameter for operation over snow or very fine sand would, therefore, be  $168$  feet.

The theoretical lines shown in Figures 126 sheet 4, 128 sheet 6 and 130 sheet 1 were calculated based on the following assumptions:

- . The downwash flow field is generated by a single jet with a uniform exit velocity profile.
- . The jet impinges normally on a flat surface.
- . The flow is incompressible.
- . The ground jet Reynold's number is constant.
- . The ground jet has its maximum extent when the nozzle height above the ground is  $3.914$  nozzle diameters.
- . The flow field produced by any aircraft, with any geometrical arrangement of propulsicn devices, may be approximated by the flow field of a single circular nozzle having an area equal to the sum of exhaust exit areas and having the same exhaust dynamic pressure.

The agreement between the theoretical calculations and experimental model data are shown in the above figures. It is considered that the data substantiates the theory well enough that the theory may be used to estimate pad sizes. However, the theory is being modified somewhat to more accurately predict downwash dynamic pressure variations throughout the flow field for any aircraft height. Predictions of optimum pad sizes will result.

#### c. Model Fence Studies

Tests were conducted to determine the feasibility of reducing the required size of the landing pad by attaching fences to the edge of the pad. Two basic types of fences were considered: (1) solid fences which cause the downwash to separate from the ground and (2) porous fences which serve to slow the downwash without separating it from the ground.

Preliminary tests were conducted on the IITV water table to qualitatively evaluate the effectiveness of several fence designs. The water table test section was setup to simulate flow in a two-dimensional wall-jet with the model fences attached to the wall of the table. The effectiveness of each fence was determined by observing the flow past the fence which was made visible by injecting dye into the water.

The results of the water table tests showed that the most effective solid fences were the ones with a sharp edge at the top of the fence and that the porous fences were effective in slowing the flow.

It was not possible to obtain quantitative data from the water table tests since the Reynold's number was quite different from that produced by actual downwash. Therefore, a test rig was constructed to provide an actual downwash flow field.

The downwash rig is similar to the one at the University of Texas in that model nozzles are attached to a plenum chamber which is attached to a compressed air supply and that the exhaust from the nozzles impinges on a large ground board. The rig has several capabilities in addition to those of the University's facility:

- . The models may be run at greater heights above the ground.
- . The downwash impingement angle may be varied from zero to ninety degrees.
- . The instrumentation is capable of measuring velocity profiles in the downwash flow along the ground.

Three tests were conducted on the downwash rig. The first test was to determine the correlation between theory and experimental data for a single uniform nozzle as a means of checking the equipment to insure its proper functioning. The second test was conducted using a model of the P-1127 to establish a correlation with and an extension of the University of Texas data. The third test was to obtain a quantitative evaluation of the downwash fences which appeared most effective in the water table test.

A sample of the results obtained in the single nozzle test is shown in Figure 132 which shows the close agreement between theory and test data.

For the second test a model of the P.1127 was constructed similar to the one used at the University of Texas. Dynamic pressures in the downwash flow along the ground were recorded along and  $90^\circ$  to the model center-line projected onto the ground. These data are presented in Figure 133 for comparison with the data from the University of Texas as shown in Figures 126, 128, and 130. Comparison of the two sets of data shows slight discrepancies at the lower model heights. For the higher model heights, the agreement is considered good. It was concluded that the correlation was adequate for purposes of establishing effects of fences on the flow field.

The fences shown in Figure 134 were selected for air flow tests based on their performance on the water table. The fences were attached in turn to the ground board as shown in Figure 135. Downwash velocity profiles were measured at several points upstream and downstream of each fence for one model height. The data obtained are shown in Figure 136 from which can be seen the effects of fence height, position, and porosity. Results are not shown for the one-half and three-quarter inch tall

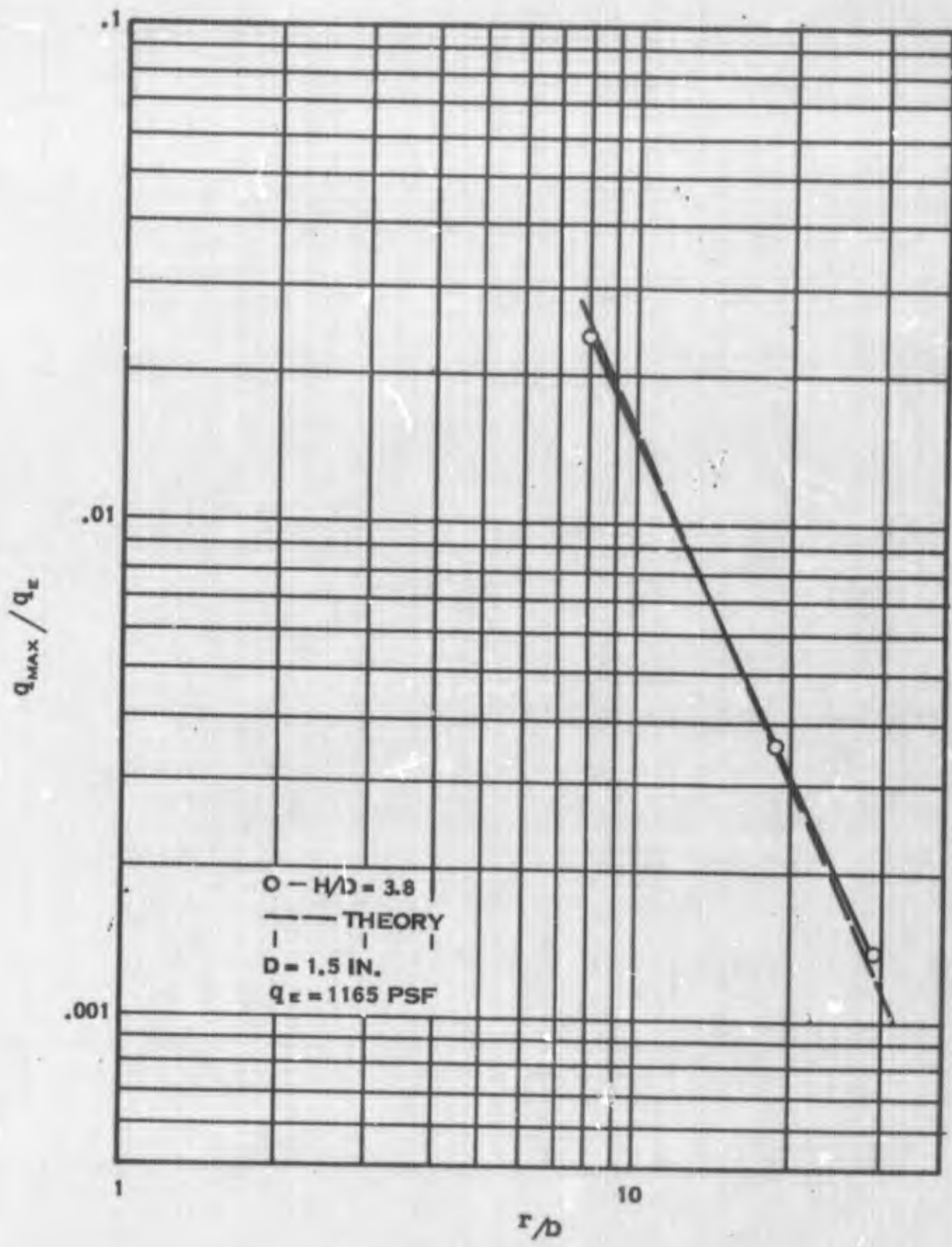


Figure 132. Comparison of Theory and Experiment for Single Uniform Nozzle

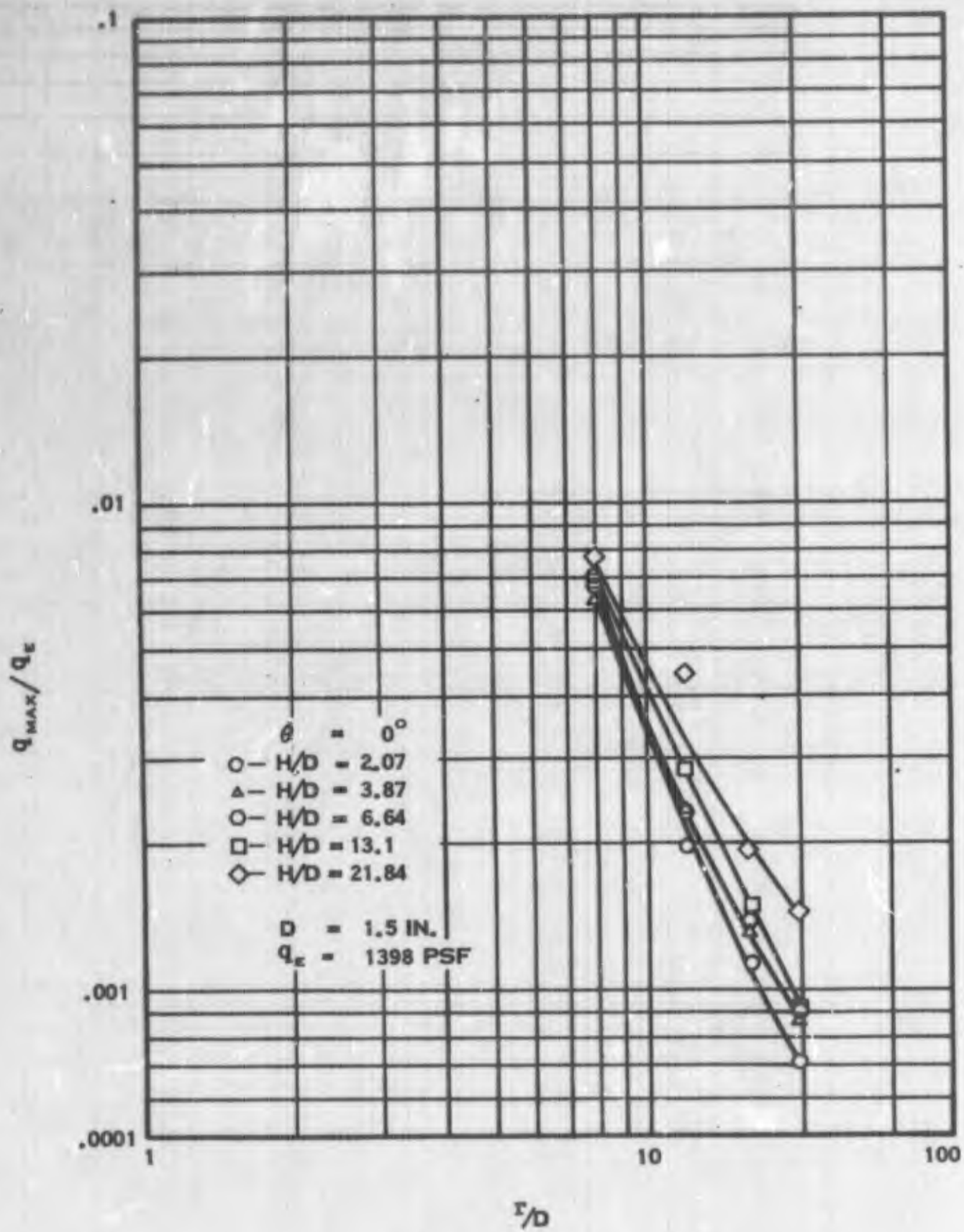


Figure 133. P.1127 Model Downwash Data From LTV (a)

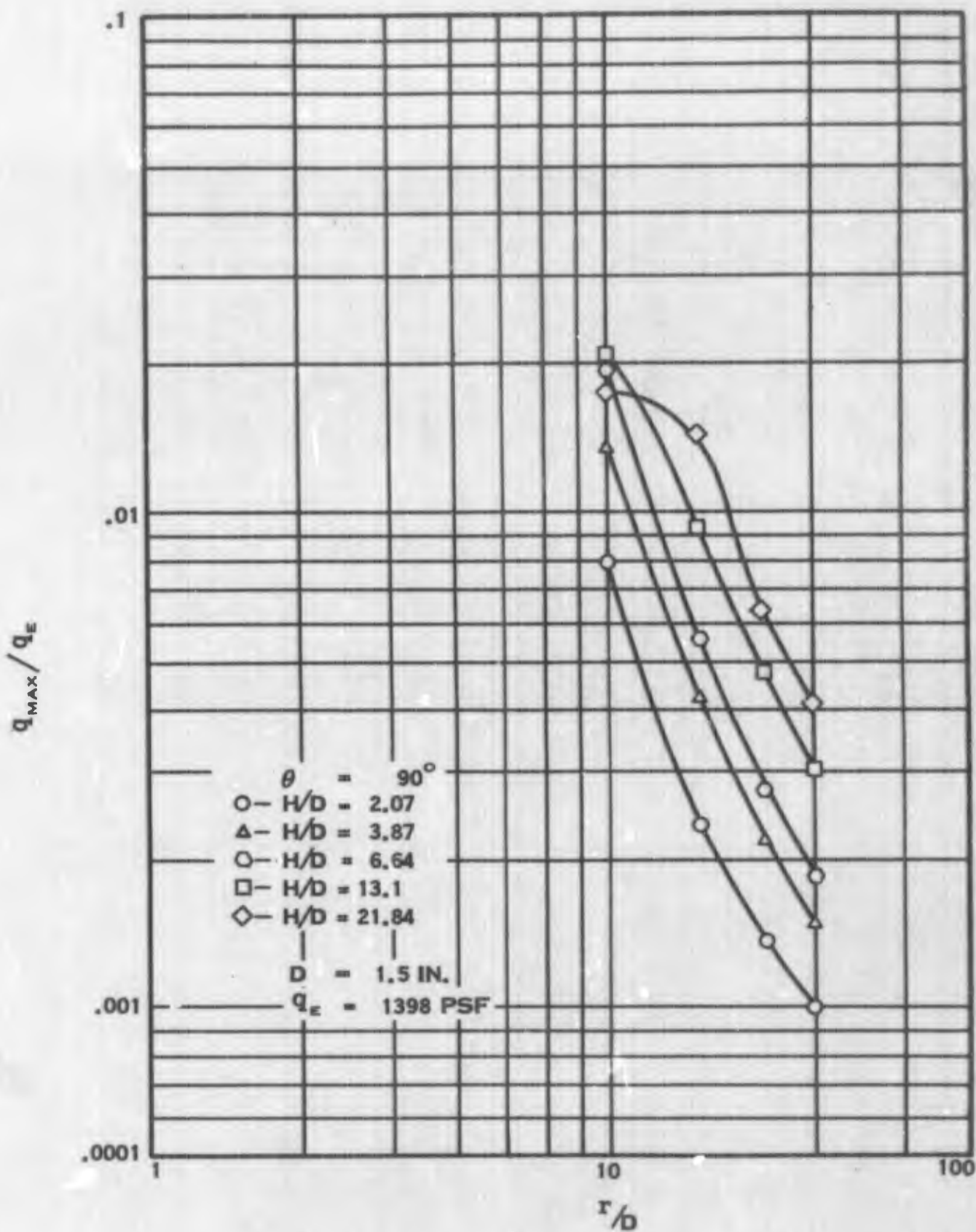


Figure 133. P.1127 Model Downwash Data From LTV (Concluded) (b)

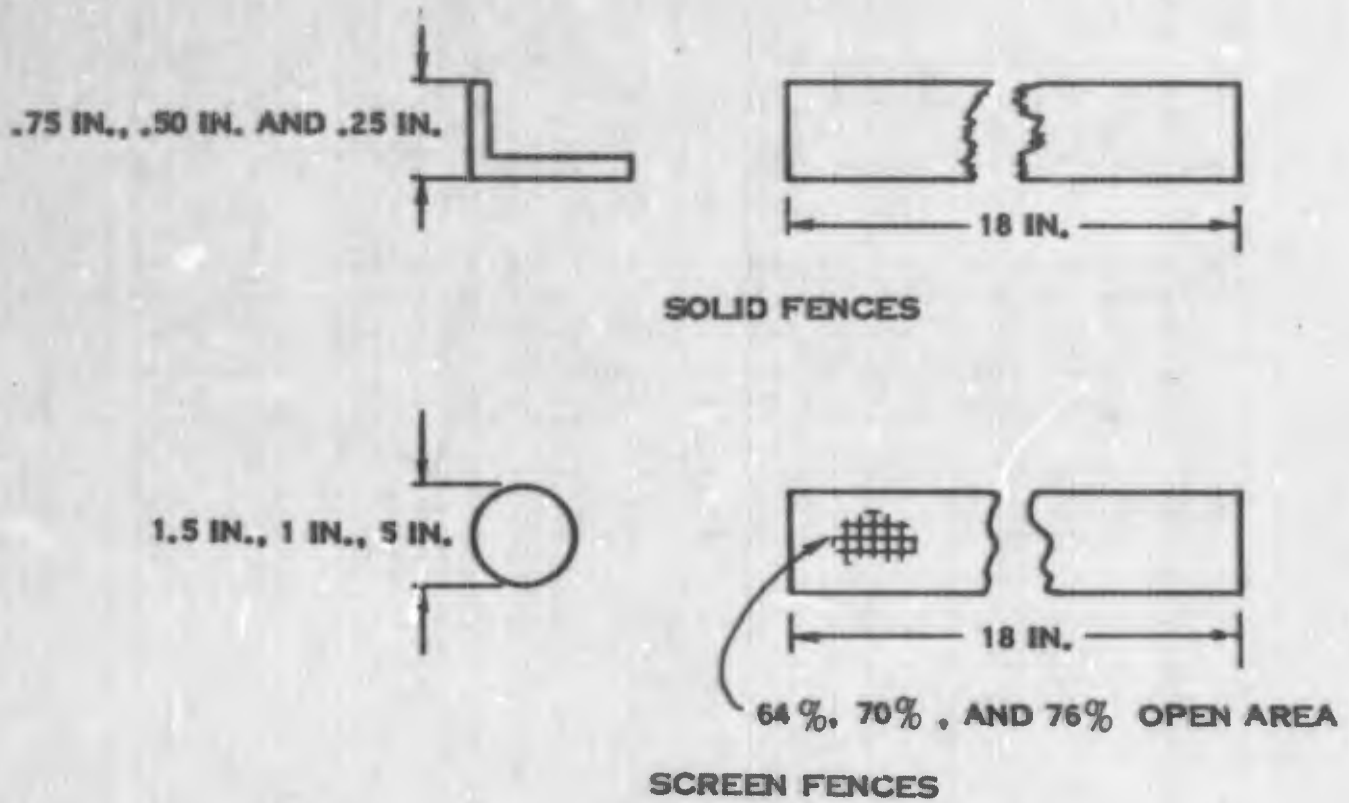


Figure 134. Fences

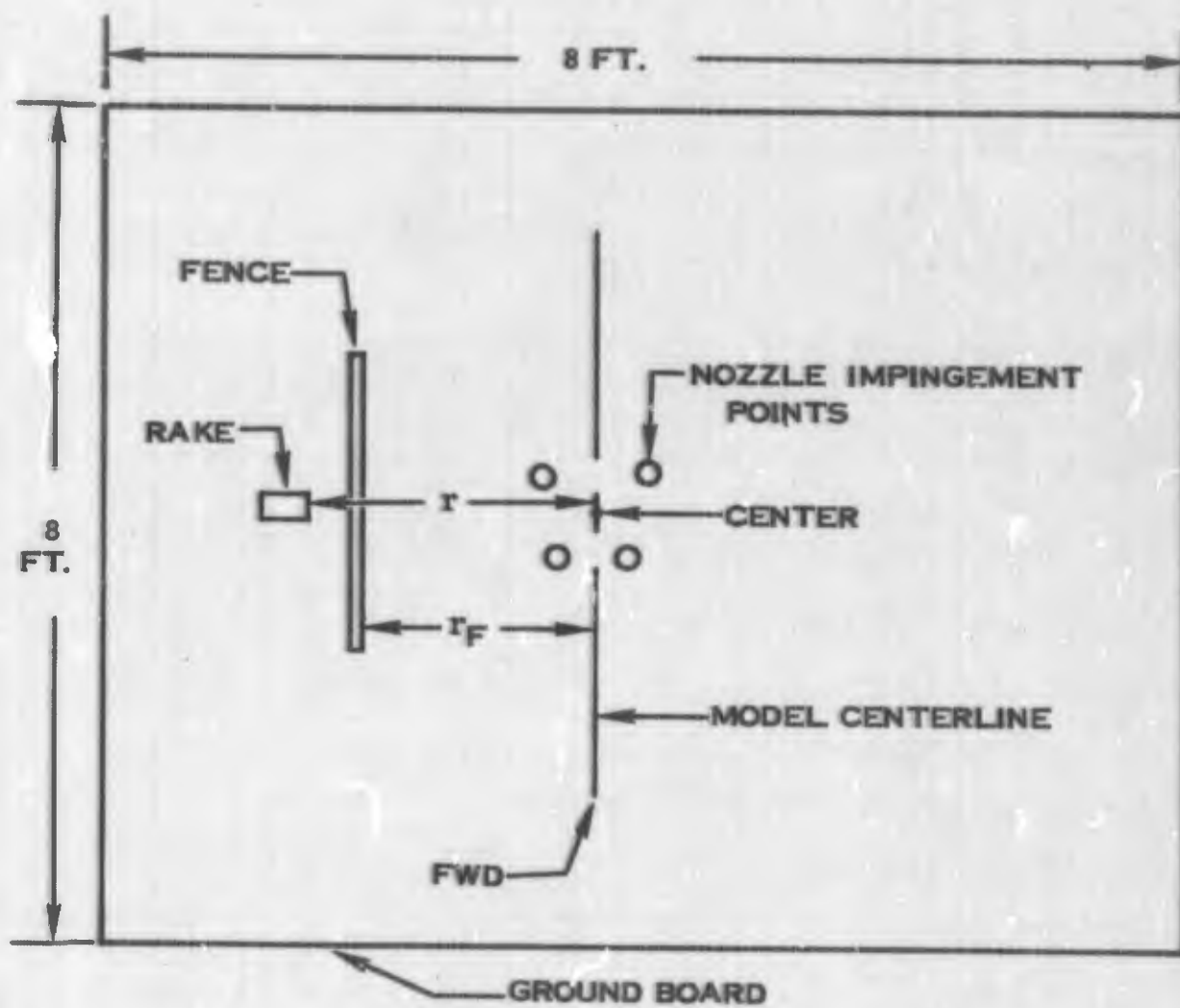


Figure 135. Fence Arrangement on Ground Board

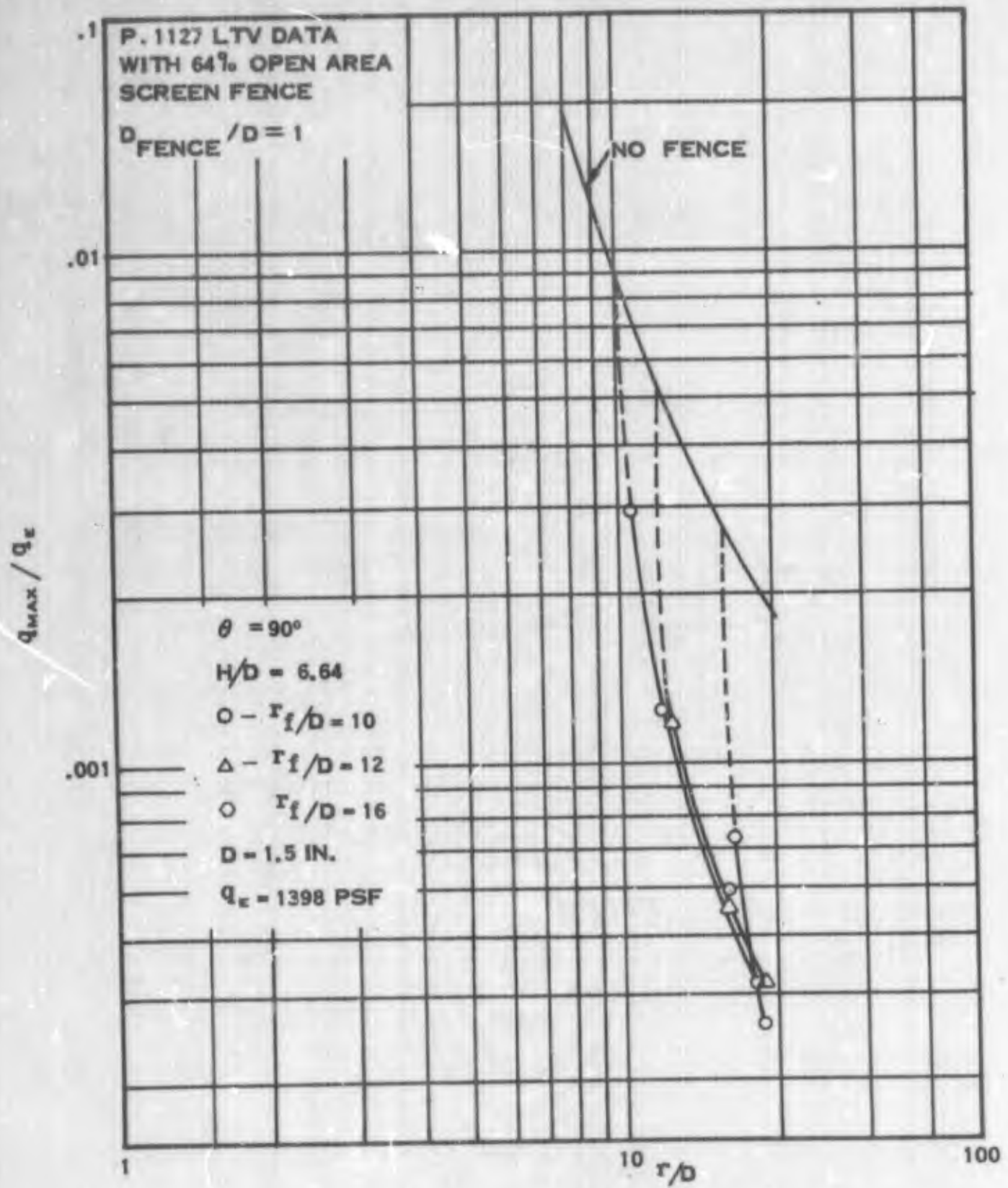


Figure 136. Screen Fence Effects in Reducing Downwash Velocities (a)

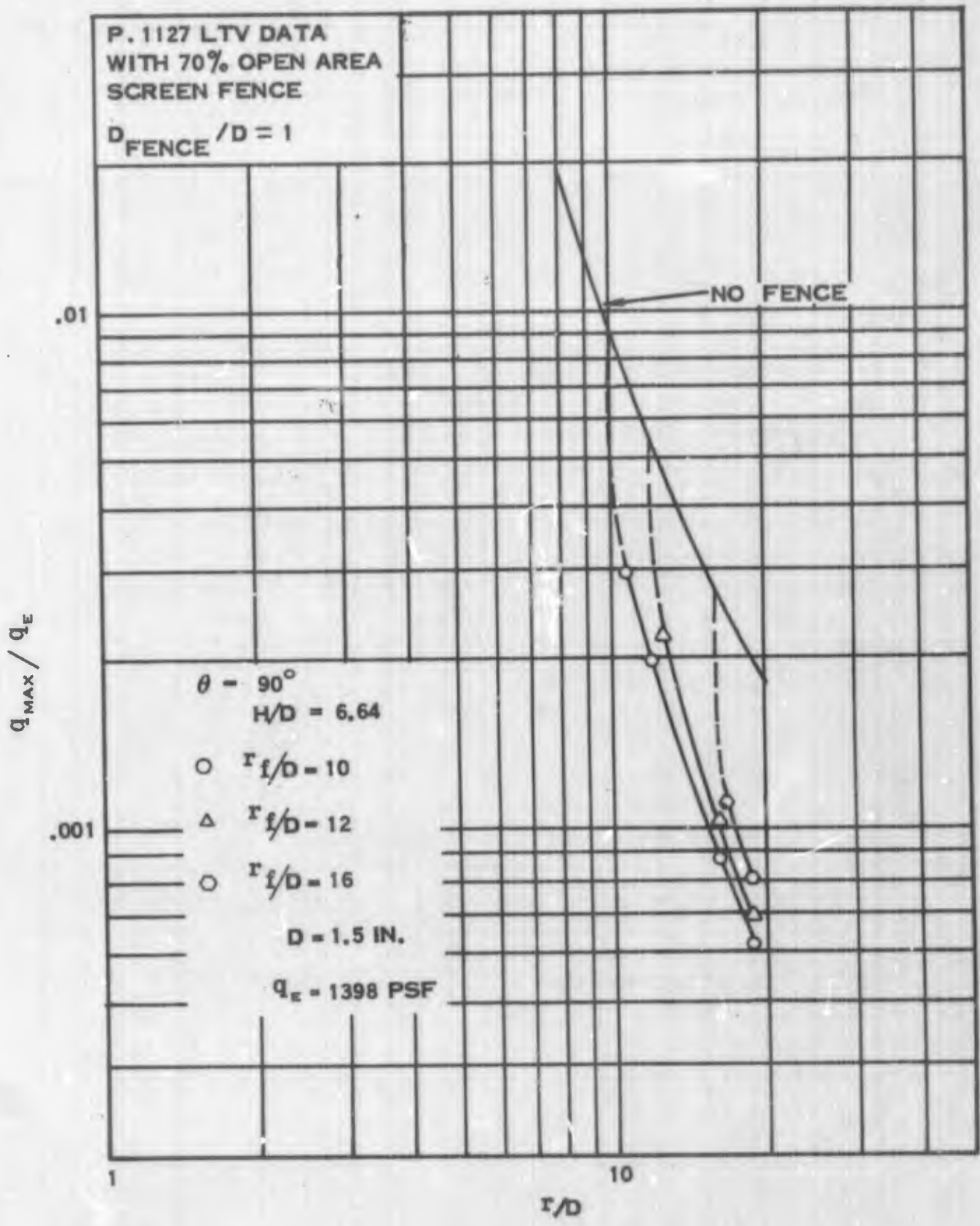


Figure 136. Screen Fence Effects in Reducing Downwash Velocities (Continued) (b)

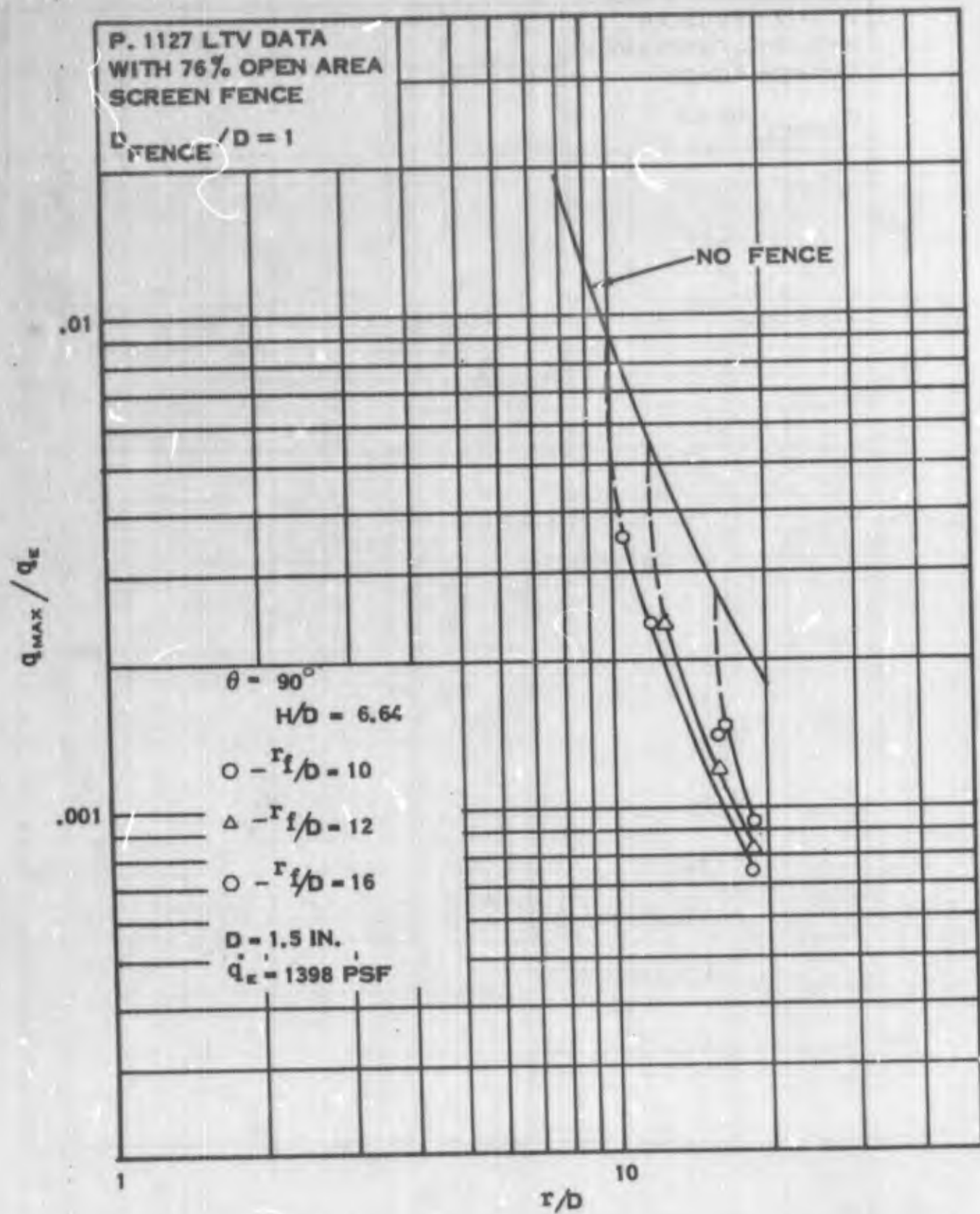


Figure 136. Screen Fence Effects in Reducing Downwash Velocities  
(Continued) (c)

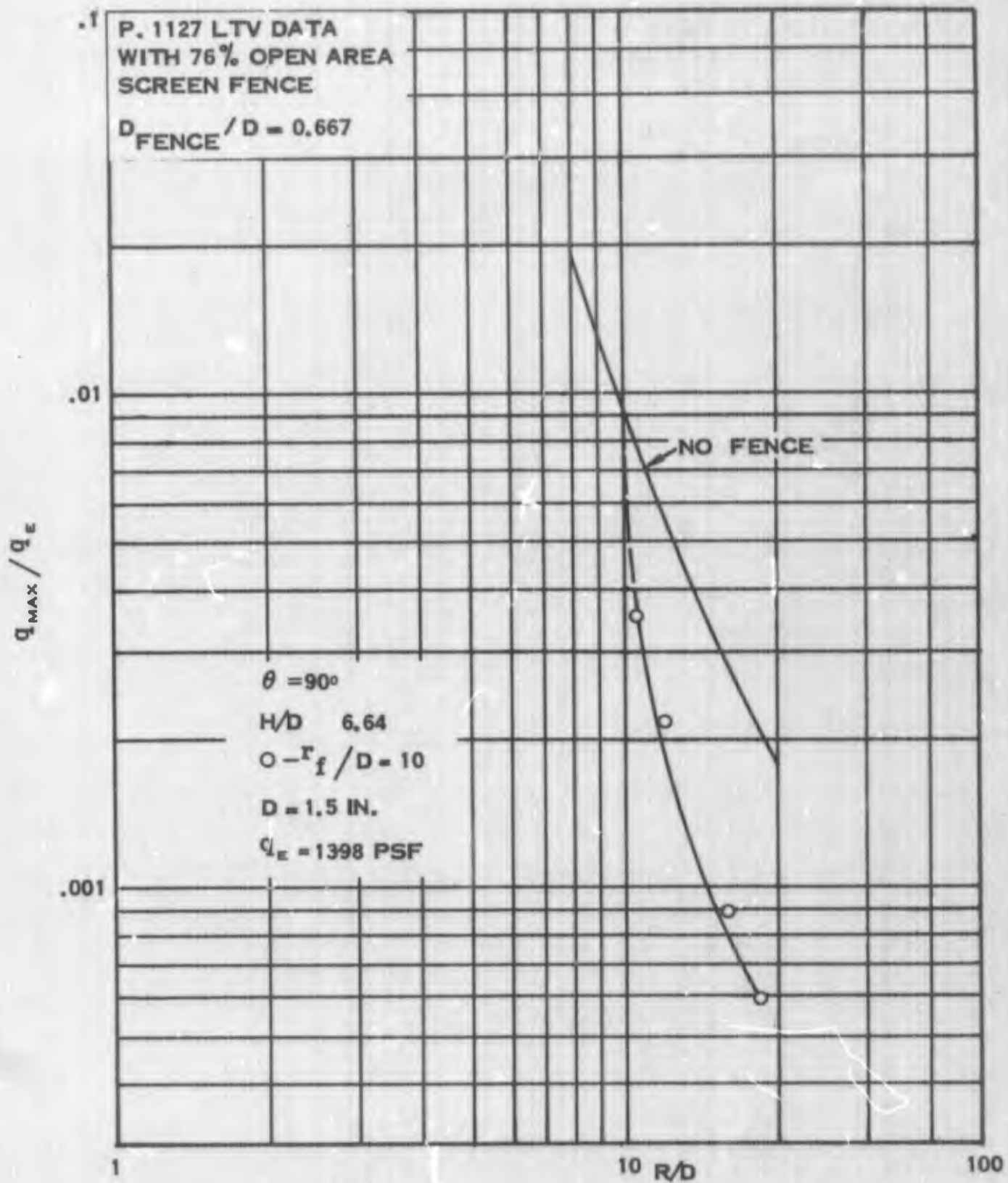


Figure 136. Screen Fence Effects in Reducing Downwash Velocities (Continued) (d)

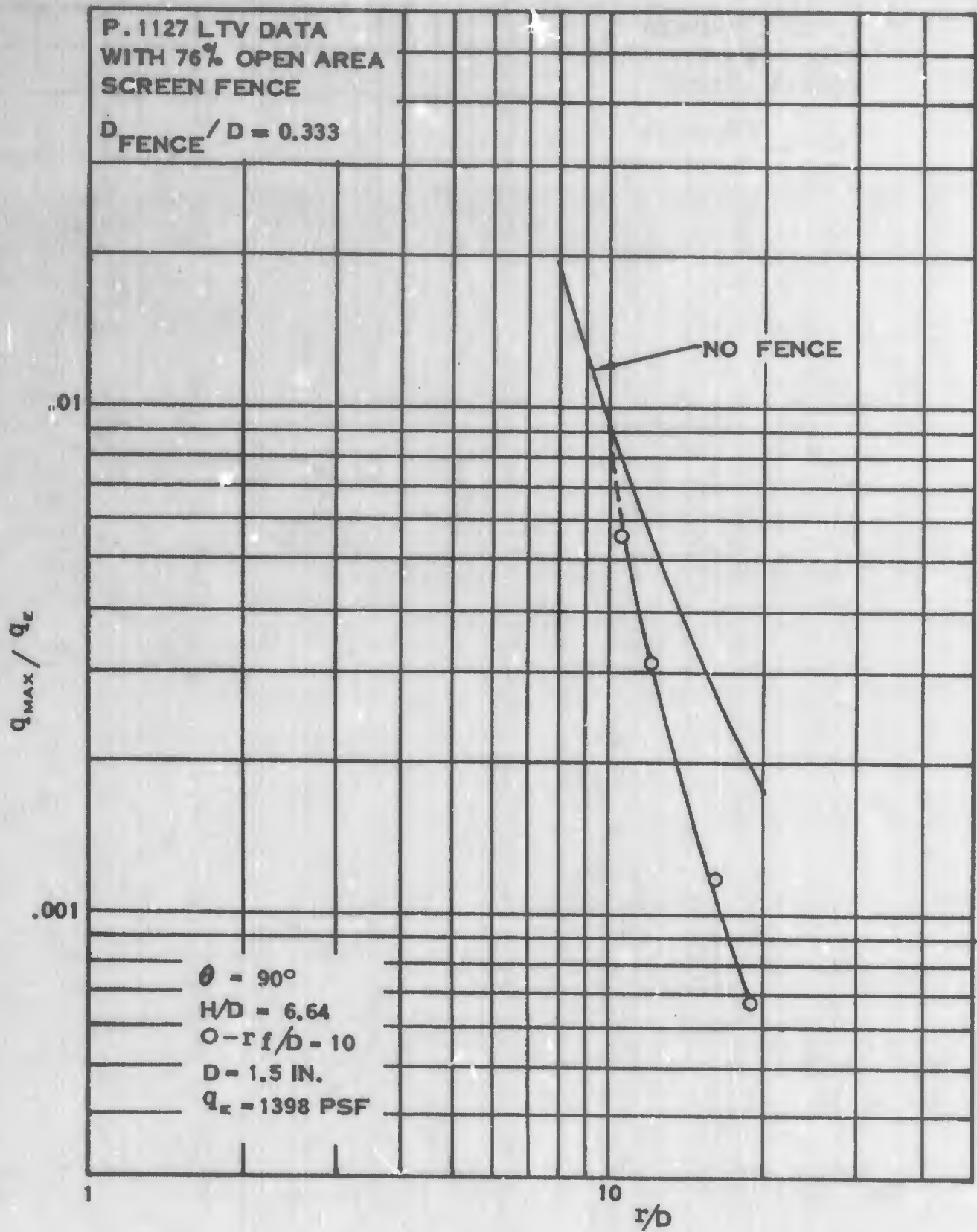


Figure 136. Screen Fence Effects in Reducing Downwash Velocities (Continued) (e)

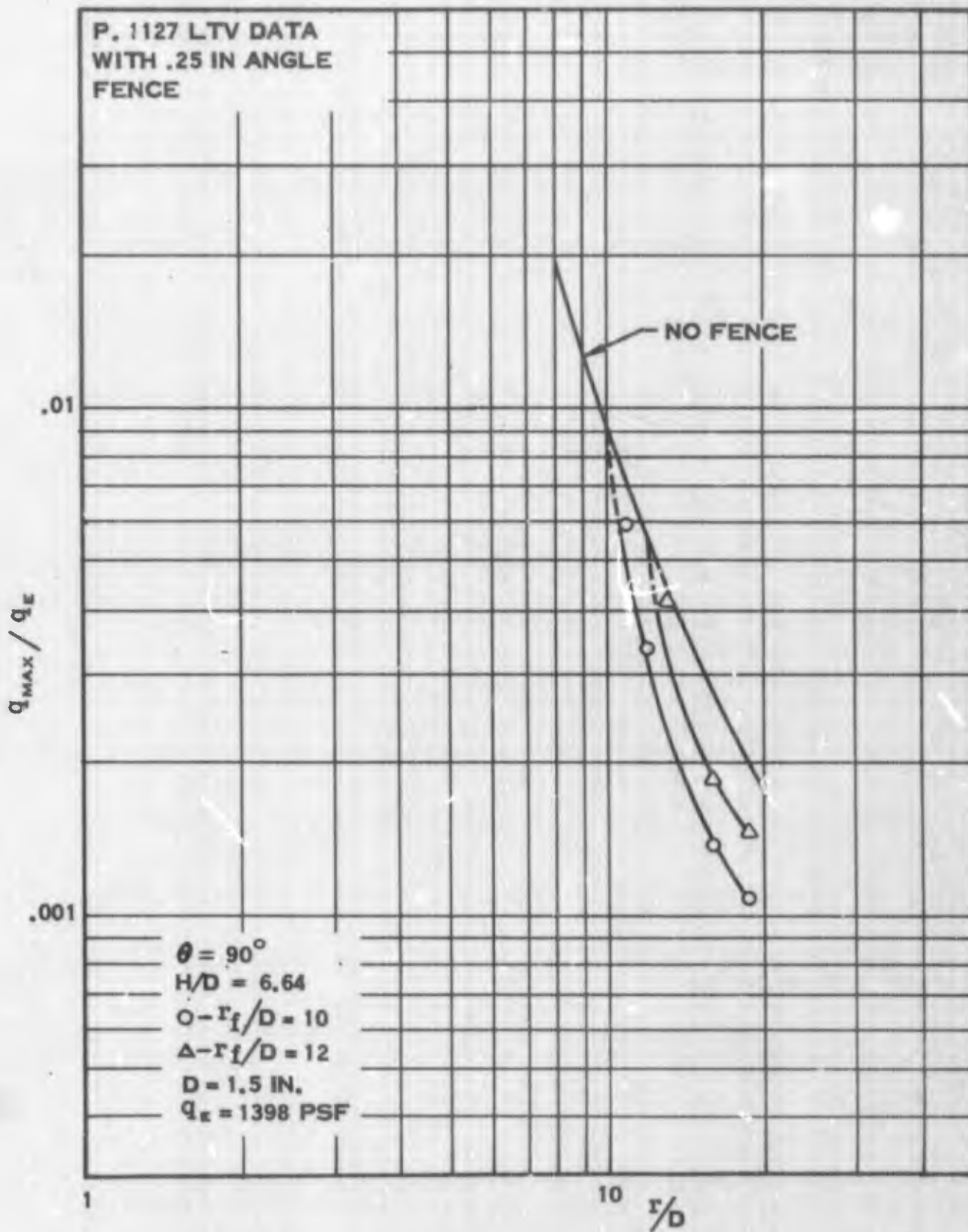


Figure 136. Screen Fence Effects in Reducing Downwash Velocities  
(Concluded) (f)

solid fences since the flow behind these fences was separated from the ground as shown in Figure 137.

As shown in Figure 136, the screen fences are effective in reducing downwash velocities along the ground without separating the downwash from the ground. The following conclusions may be drawn from the data:

- . The downwash velocity change across the fence increases with decreasing screen open area. However, a minimum limit for screen open area exists in that spillage over the top of the screen will become too great if the open area is too small thereby making the screen behave as a solid fence.

- . For the test condition run, the fence height for maximum velocity loss appears to be 0.667 nozzle diameters, but the velocity loss for the other heights is almost the same. It, therefore, appears that actual fence height has little effect so long as the height is somewhat greater than the boundary layer thickness.

- . As an example of the reduction in pad diameter required, consider the case for a soil surface for which an erosion threshold  $q_{max}$  is 3 psf. The pad diameter required for the P.1127 with no fence would be 100 feet. With a one-foot diameter roll of screen wire placed around the pad 6 feet in from the edge, the pad diameter required for 3 psf at the edge would be 73 feet - a reduction of 27 feet for an area reduction of 4700 square feet. It should be remembered that this example is based solely on model test data and that scale effects, such as Reynold's number, could alter the requirements somewhat. Full scale tests are required to substantiate the model data and conclusions made.

Results of the solid fence tests indicate that solid fences may not be practical for turbojet powered aircraft since these fences separate the downwash from the ground and create vertical velocity components. These vertical velocities will aggravate the hot gas reingestion problem common to most turbojet aircraft. The solid fences may, however, be practical for other types of aircraft having "cool" downwash. In this case, reingestion is not as great a problem.

For the test conditions run, the results quoted in the screen fence example above are the same for a solid, vertical fence 6 inches tall.

#### d. Site Flow Field Measurements

Downwash dynamic pressures and temperatures were recorded at the edge of the pad for several vertical landings and takeoffs of the P.1127 VTOL aircraft in England and the VJ101 VTOL aircraft in Germany. Instrumentation consisted of five pressure-temperature rakes positioned in one quadrant of the pad as shown in Figures 142 and 148 (see Section V). Each rake contained three total pressure probes and one total temperature thermocouple. Each pressure was converted to an electrical signal by a

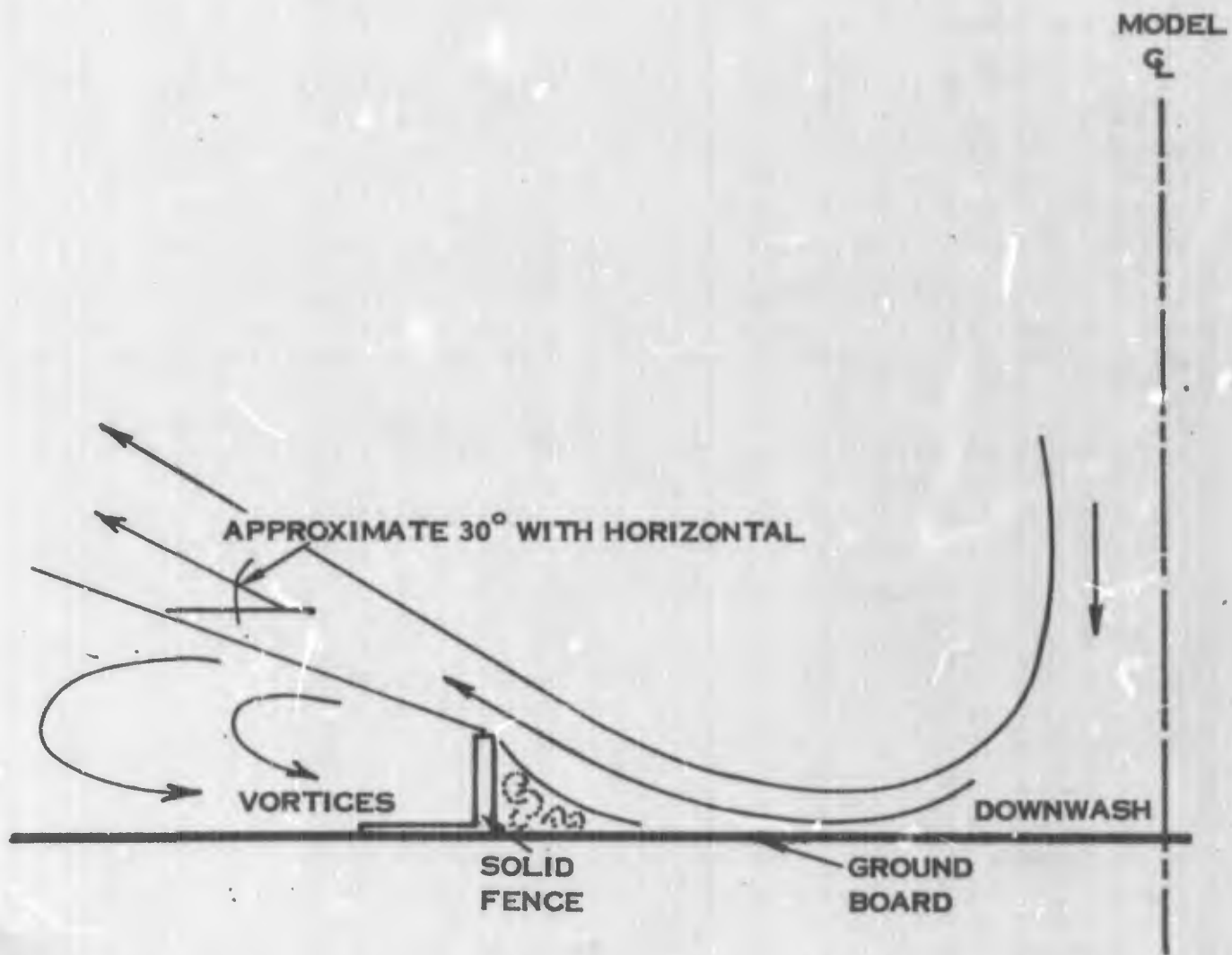


Figure 137. Separated Flow Behind Solid Fence

differential pressure transducer. The outputs of the transducers and thermocouples were continuously recorded by a light beam recording oscillograph. The position of the aircraft relative to the pad was recorded by two motion picture cameras positioned on pad counterlines at right angles to each other.

In analyzing the data from the P.1127 and VJ101 flights, two averaging techniques were employed to reduce the variation in the independent variables ( $\alpha$ ,  $\theta$ , and H) and to reduce the scatter in the data. The first reduction was to assume that the height, H, was constant. According to the theory, this assumption introduces a maximum error of about plus or minus 8 percent for  $q_{max}$ . The other technique was to average the data over 10 degree increments in  $\theta$ . The temperatures were essentially equal to ambient, and therefore are not shown.

The flight test data recorded for the P.1127 are of qualitative value only since one of the instrumentation cameras failed. This failure made the accurate determination of the aircraft position relative to the total pressure rakes impossible. However, the aircraft position was determined approximately from the motion picture film from the camera looking head-on at the aircraft.

The results of the flight test data reductions are shown compared with the model test data in Figure 138. The solid lines are drawn through the model data. The large amount of scatter in the VJ101 flight test data makes it difficult to draw conclusions. However, since the flight test data in general brackets the model test data, it appears safe to conclude that the model adequately simulated the complex full-size flow field. It would not be appropriate to compare P.1127 flight test and model test data because of the error introduced when the camera failed. However it is encouraging to note that the model test data and theoretical predictions show good agreement.

#### e. Aerodynamic Pad Lifting Forces

The pouring or laying or spraying of rapid site landing mats over unprepared ground leads to surface irregularities on the mat. These irregularities or bumps when subjected to downwash velocities produce aerodynamic forces which may lift a portion of the mat.

The problem of landing mat lifting was approached assuming the bumps to be of cylindrical shape as shown in Figure 139. This shape was chosen due to its simplicity and relatively large pressure coefficients which will tend to give conservative results. The results as shown in Figure 140 were obtained from a test carried out using the LTV water table. The test was conducted to simulate a downwash Mach No. of 0.5 as this closely simulates, within the limits of the water table, the flow velocities of a turbojet VTOL aircraft downwash.

The forces produced on the mat are related to the pressure coefficient by the following equation (1):

$$F = \int C_p q_{\infty} dx$$

where:  $C_p$  = pressure coefficient =  $(P_{local} - P_{\infty})/q_{\infty}$   
 $q_{\infty}$  = free stream dynamic pressure - PSF  
 $dx$  = an incremental length - ft.

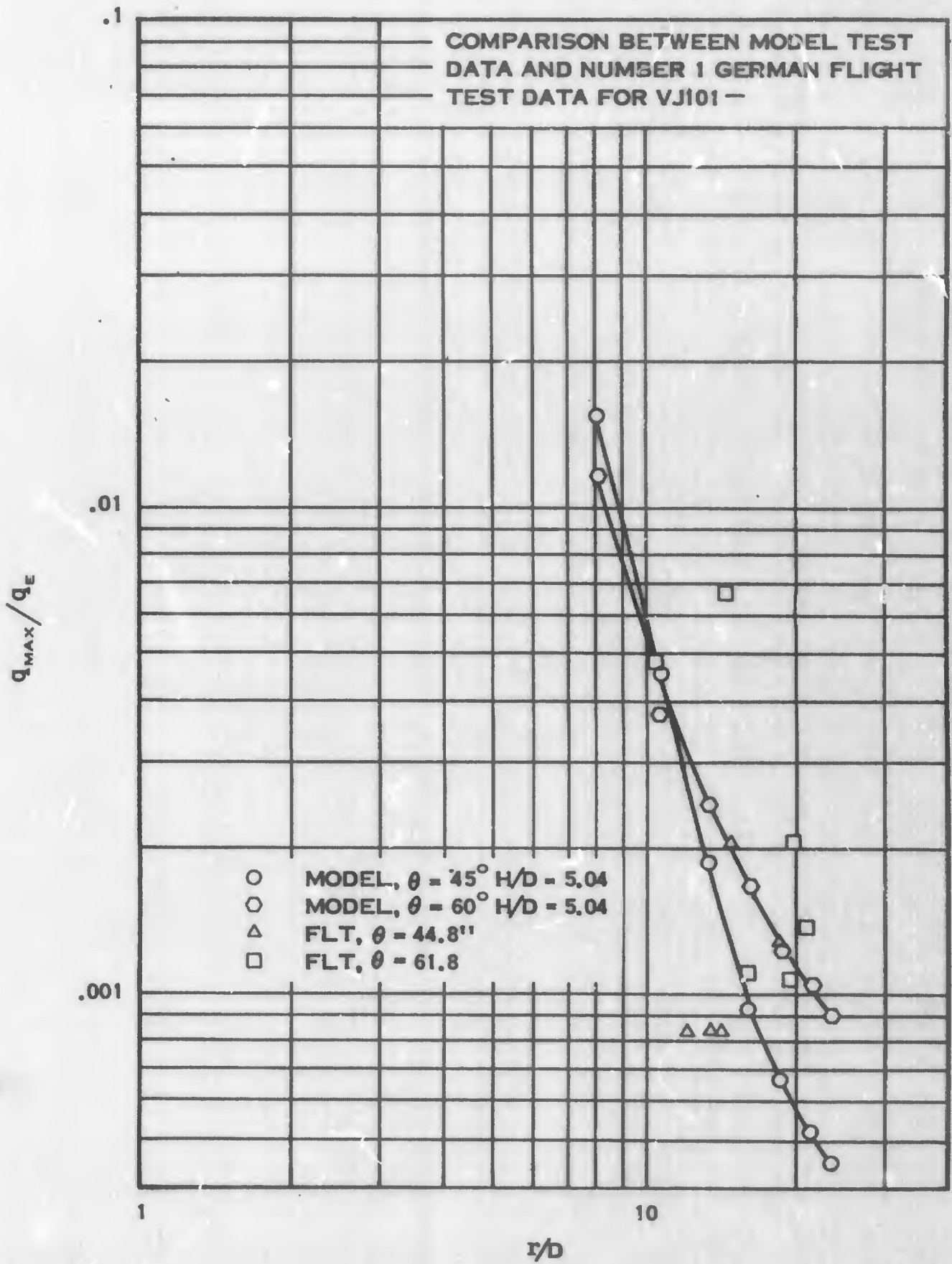


Figure 138. Comparison Between Flight Test Data and Model Test Data (a)

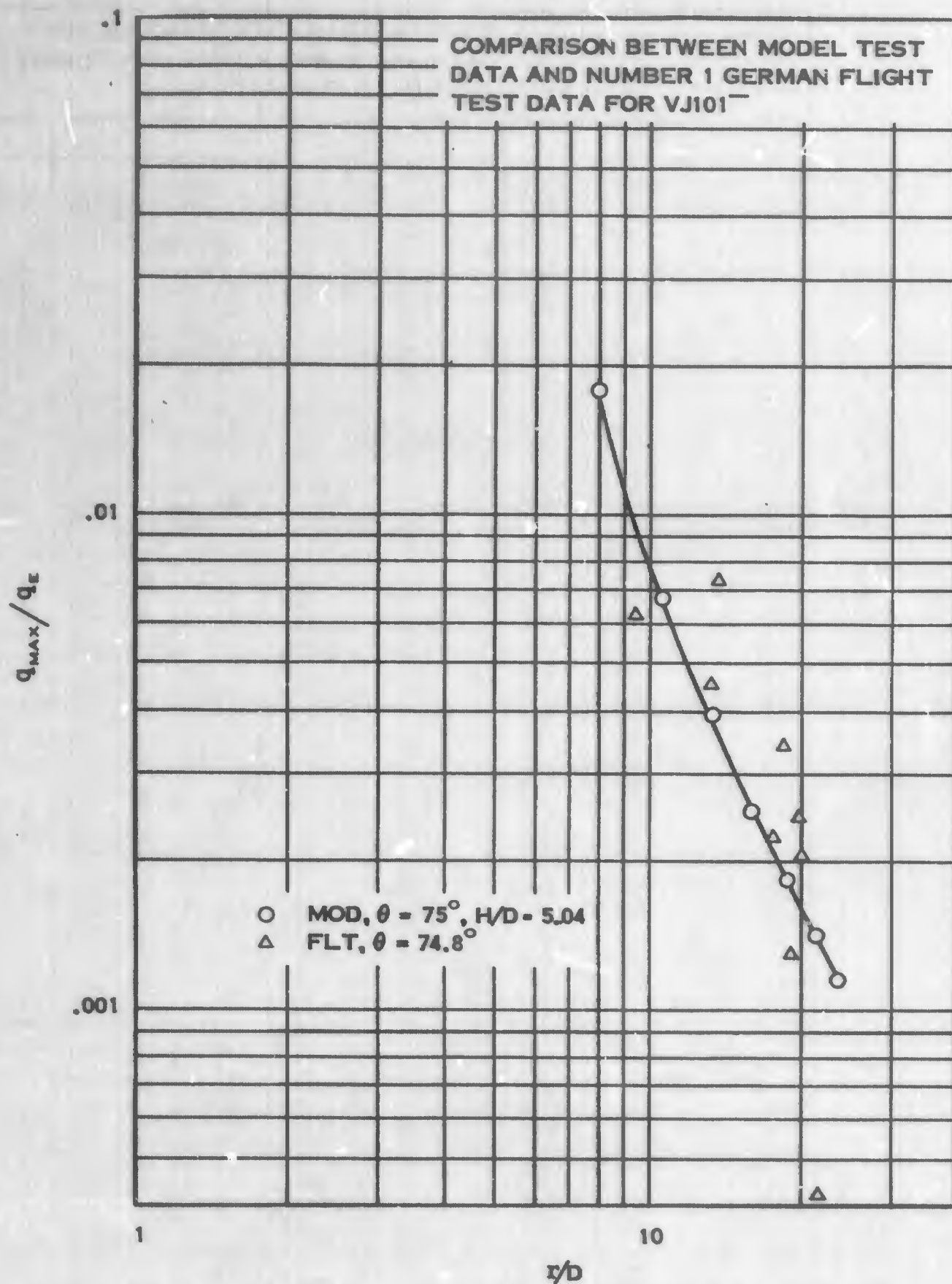


Figure 138. Comparison Between Flight Test Data and Model Test Data (Continued) (b)

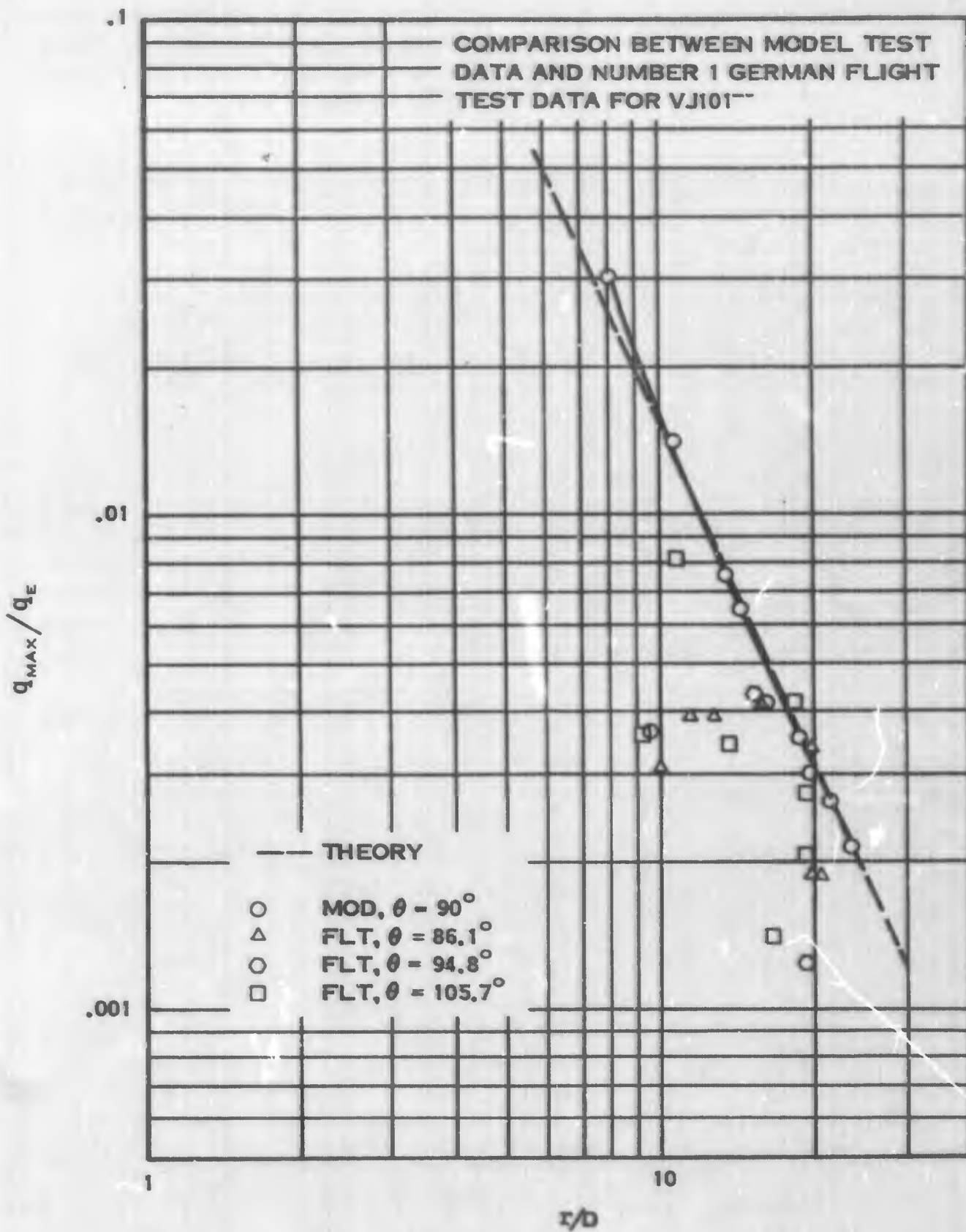


Figure 138. Comparison Between Flight Test Data and Model Test Data (Continued) (c)

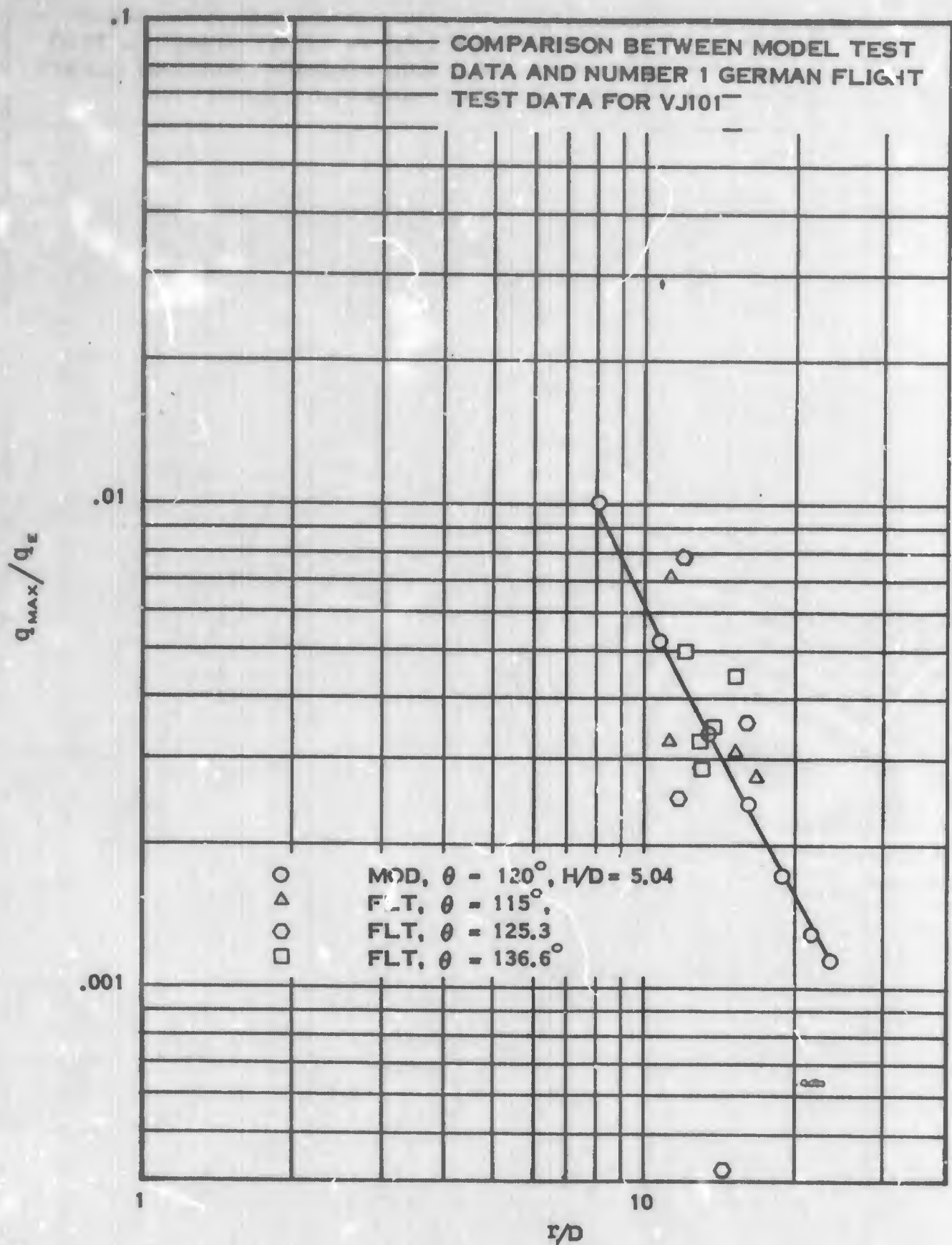


Figure 138. Comparison Between Flight Test Data and Model Test Data (Continued) (d)

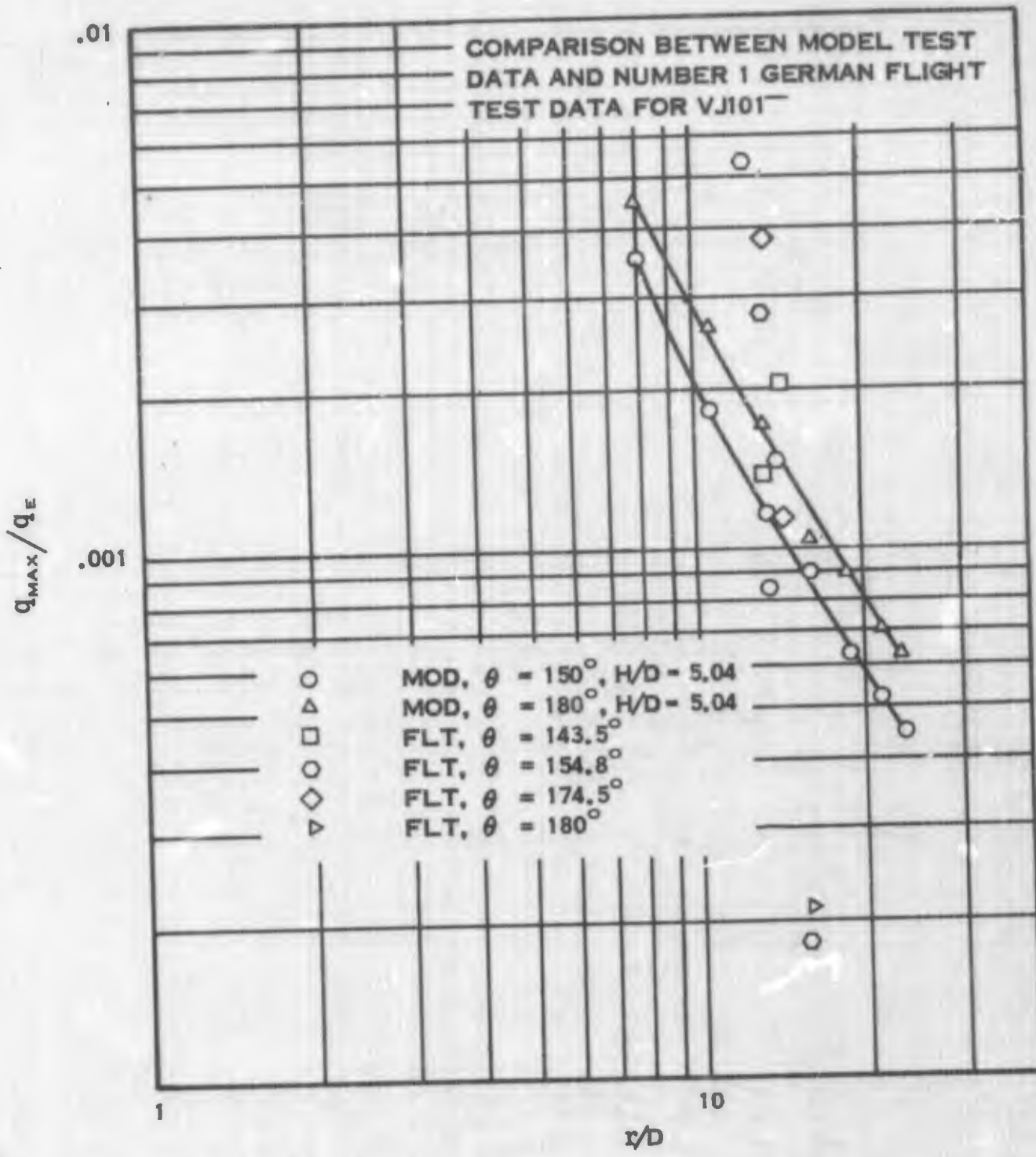


Figure 138. Comparison Between Flight Test Data and Model Test Data (Continued) (e)

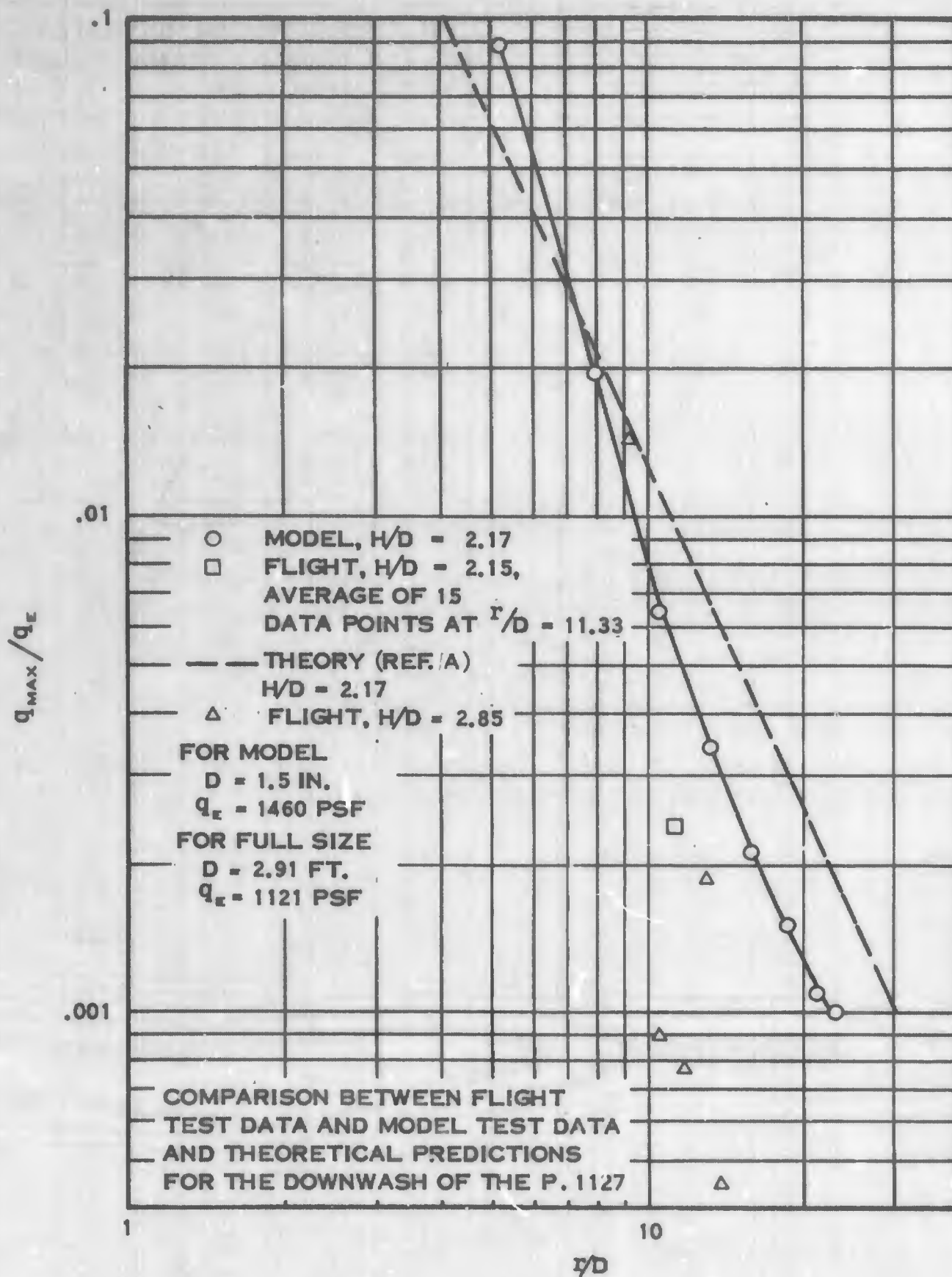


Figure 138. Comparison Between Flight Test Data and Model Test Data (Continued) (f)

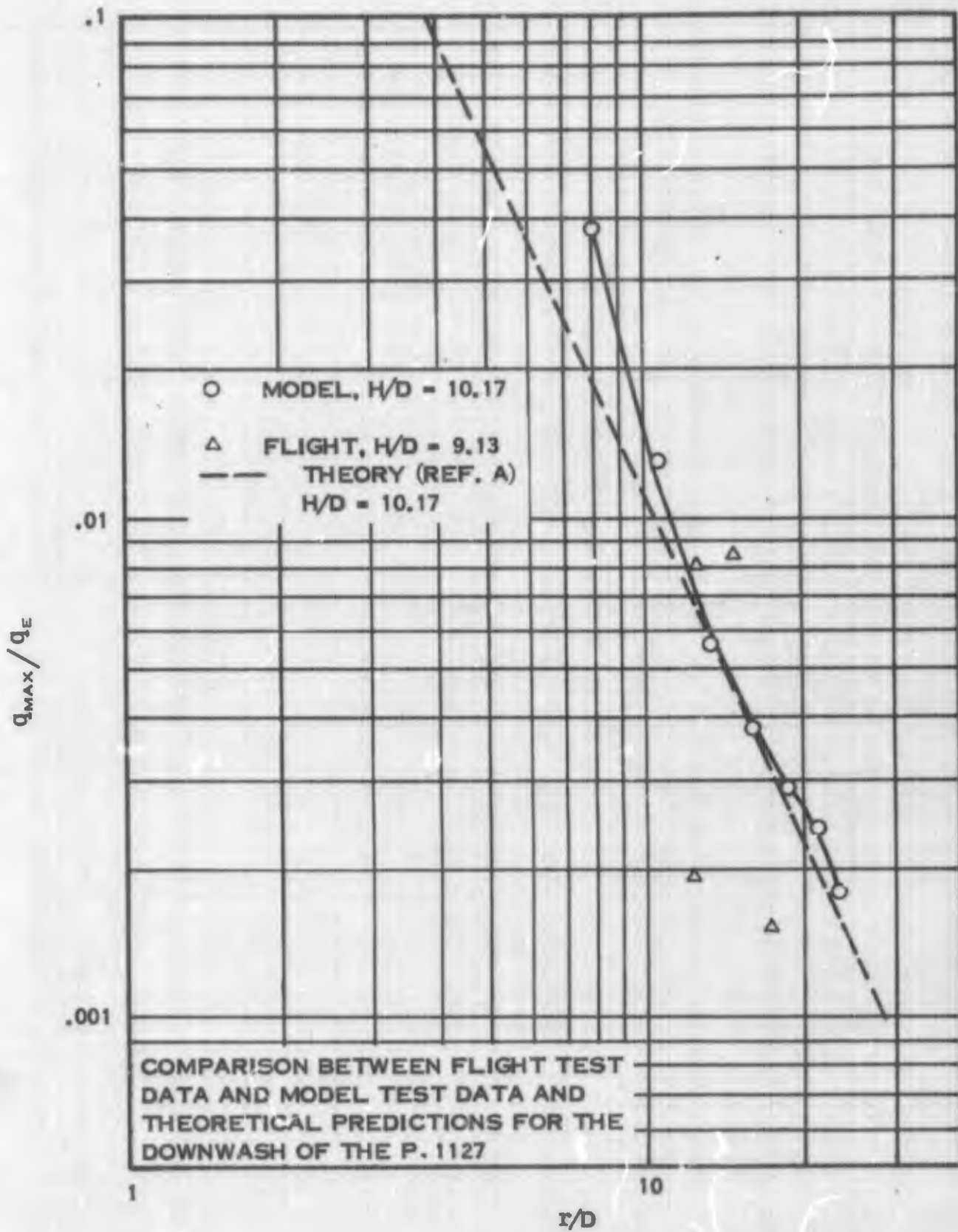


Figure 138. Comparison Between Flight Test Data and Model Test Data (Continued) (g)

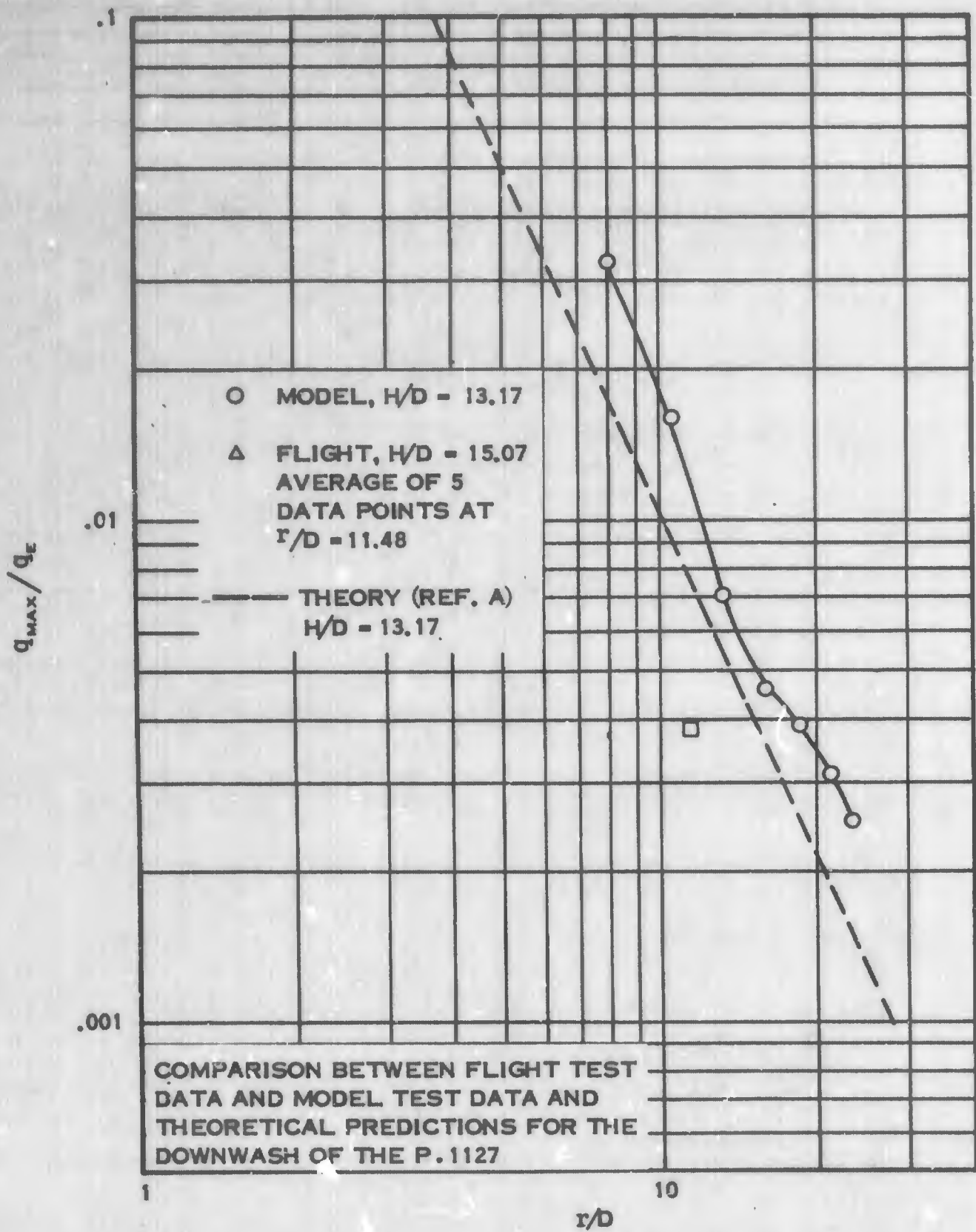
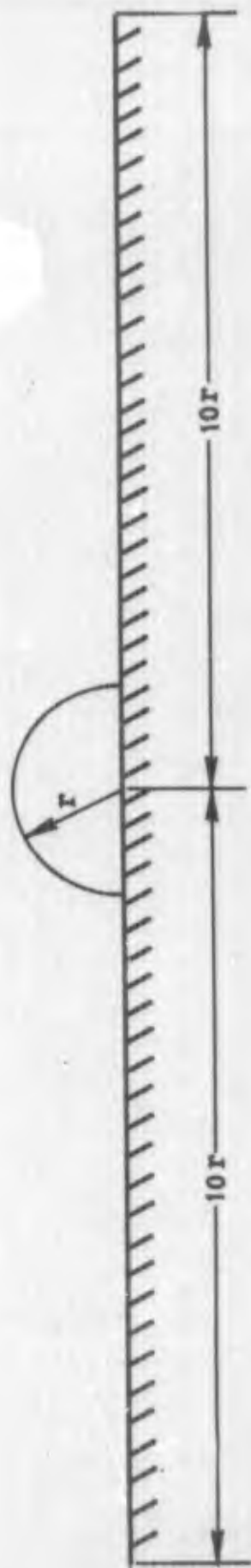


Figure 138. Comparison Between Flight Test Data and Model Test Data (Concluded) (h)



WATER TABLE TEST MODEL FOR DETERMINING  
PAD LIFT FORCES

Figure 139. Water Table Test Model for Determining Pad Lift Forces

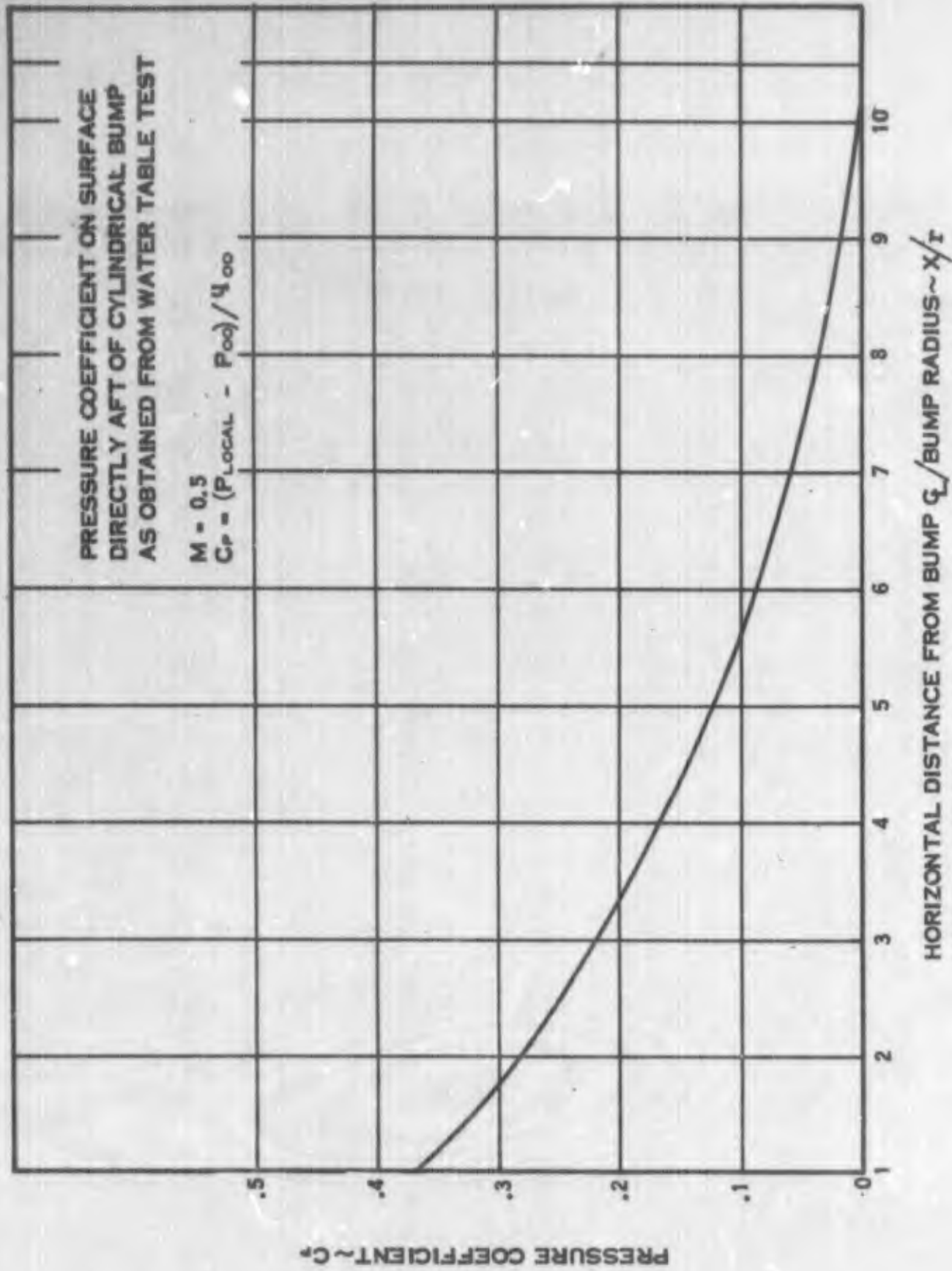


Figure 140. Pressure Coefficients As Obtained From Water Table Test (a)

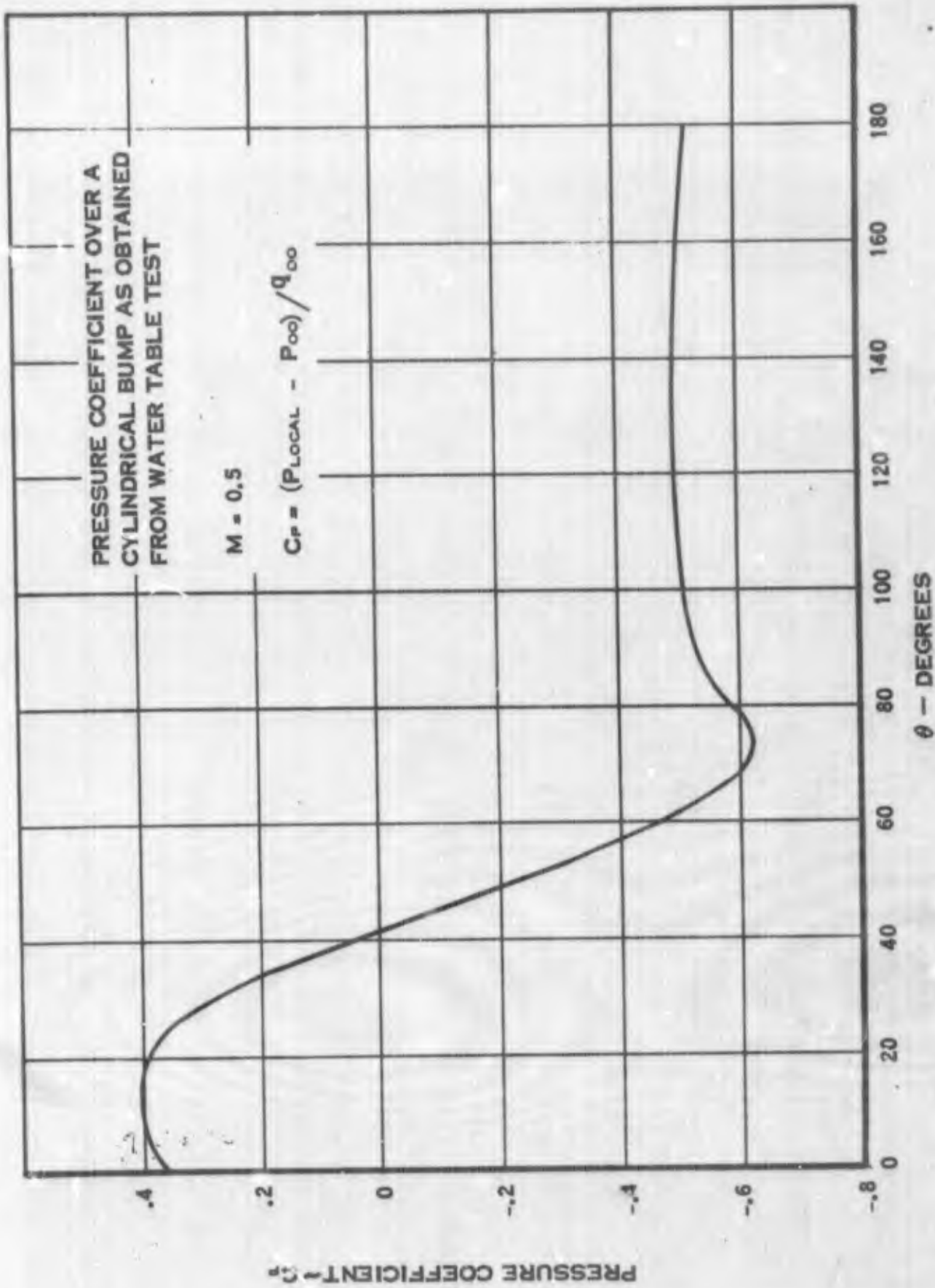


Figure 140. Pressure Coefficients As Obtained From Water Table Test  
(Continued) (b)

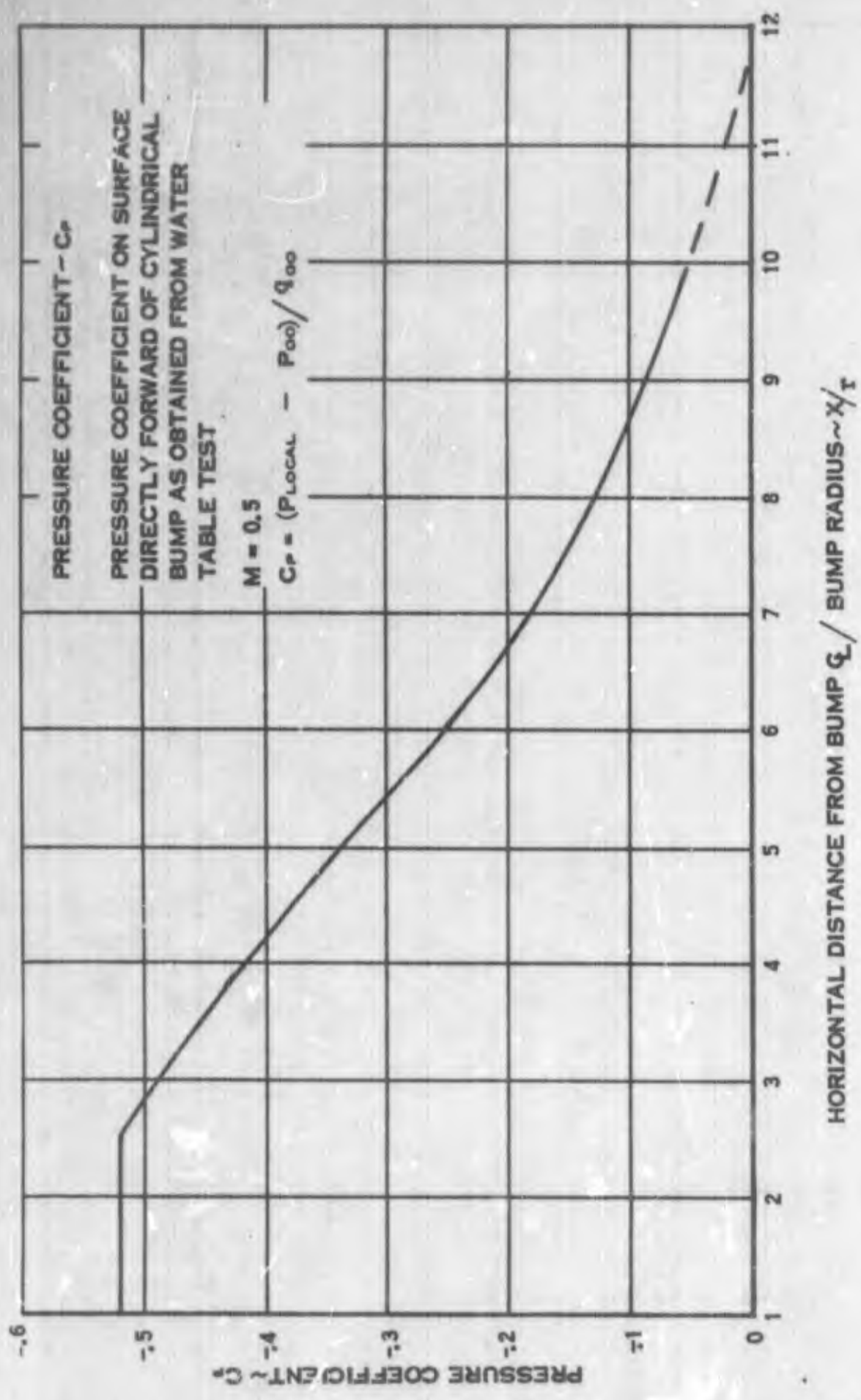


Figure 140. Pressure Coefficients As Obtained From Water Table Test (Concluded) (c)

The most severe condition for mat lifting is the case where the bump is located on the edge of the mat. In this case the downward force, Figure 140, sheet 1 produced on the mat ahead of the bump is not present and the lifting or upward force is at a maximum for an aircraft approaching the edge of the mat.

Using equation (1) the force on a bump and associated mat located at the edge of the mat is:

$$F = 3.47 q_{\infty} r$$

where r is the radius of the bump in feet, and the force is given in pounds per foot of bump width.

Some examples of the possible lifting forces obtained with various VTOL aircraft approaching the edge of a landing mat at a height of 25 feet are as follows:

	<u>q<sub>max</sub> ground</u>	<u>Bump Radius</u>	<u>Lifting Force</u>
XC-142	51 psf	2 inches	29 lb/ft
P. 1127	383 psf	2 inches	222 lb/ft
VJ101	462 psf	2 inches	267 lb/ft
DO-31	760 psf	2 inches	440 lb/ft

Typical mat densities range from 2 to 5 psf. The mat weight or restraining force expressed in pounds per foot of bump width range from 3.7 to 9.2 lb/ft. A comparison of this force to the above lifting forces show that if proper edge restraint is not employed the mat edge will lift. Once the edge begins to lift, the downwash will get under the mat and fold back or lift the remainder of the mat.

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## SECTION V

### REMOTE SITE PREPARATION

#### 1. BASIC TECHNIQUES

The general process for fabrication of remote sites is outlined as follows:

##### a. Equipment

The required equipment consists of:

(1) The WM-300 Dodge truck prime mover with application equipment as described in Section III.

(2) Resin tank trailer, 400-gallon capacity, four required.

(3) Miscellaneous equipment

- (a) Handling
- (b) Cleaning
- (c) Safety and personal
- (d) Site layout

Equipment operational procedures are shown in reference (4), superseding those of reference (3). The latter was used for the European tests to be described in this section.

##### b. Site Fabrication Procedure

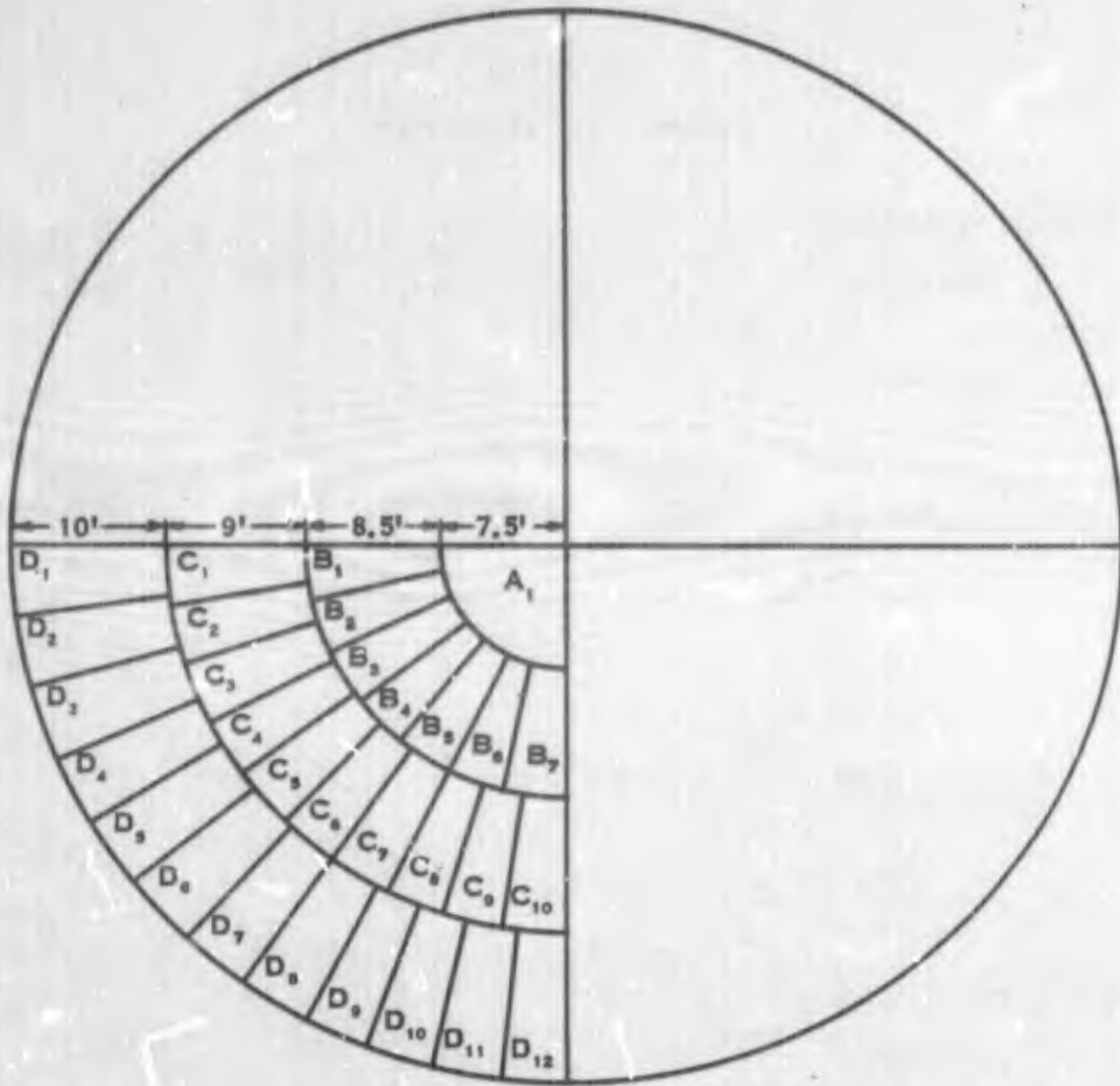
(1) Preliminary

Site preparation requires the following preliminary steps:

The application equipment must be loaded with necessary raw materials (resin, glass, catalyst, solvent).

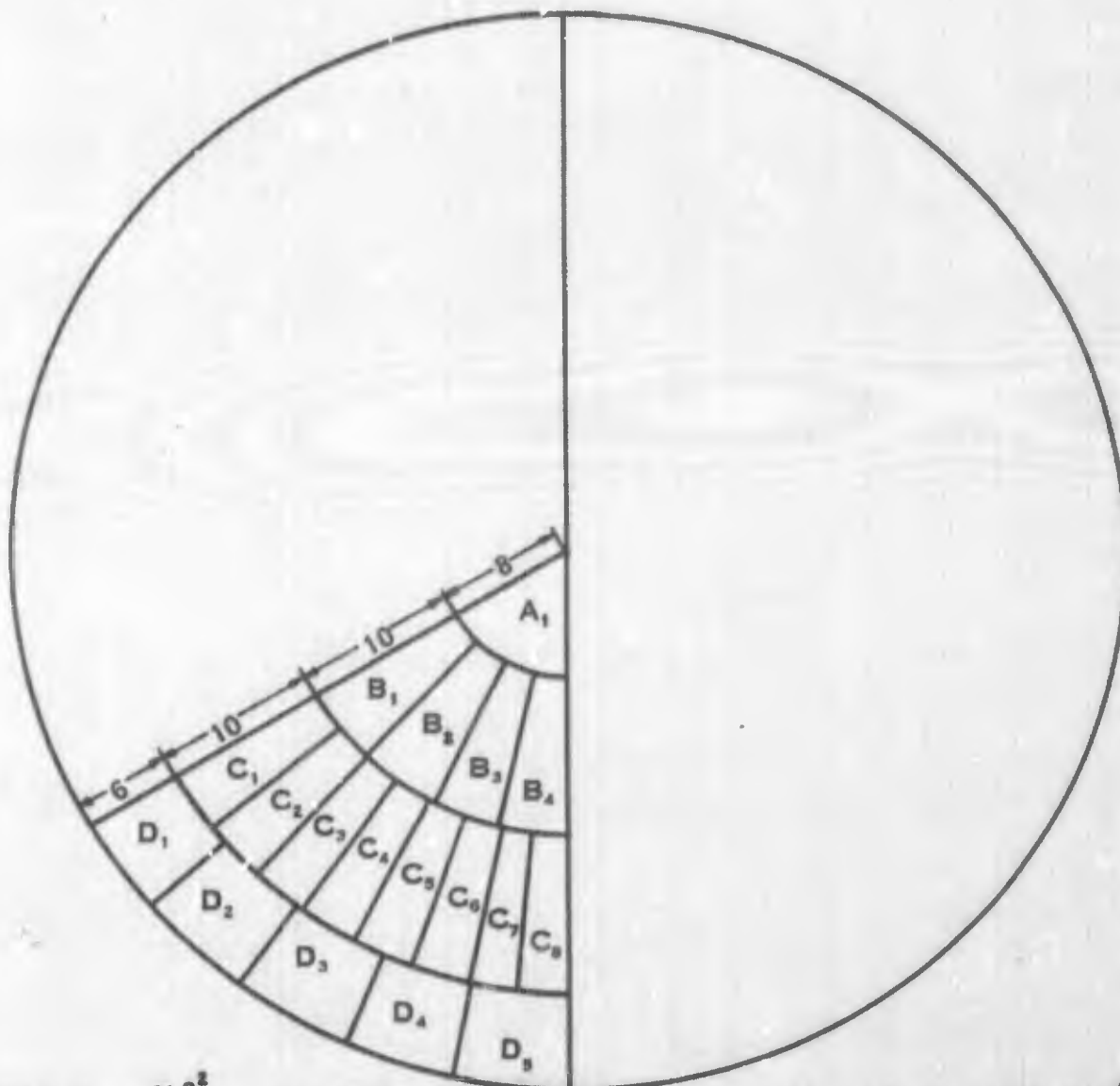
Minor site obstructions (small shrubs, rocks, etc.) must be removed. This includes the mowing of high grass.

The site must be laid out into convenient sections to assist in even distribution of the material. Each section should be three to six feet wide and of proper area to require ten (or a multiple of ten) gallons of resin per section. A small area at the center of the site may exceed the six foot dimension as this area may be sprayed from various positions more readily than subsequent sections. Figures 141 and 142 show typical layouts. An athletic field line marker has been used in Phase I for site layout.



AREA A <sub>1</sub> = $\frac{\pi}{4} (7.5)^2 = 44.2$	$\frac{44.2 \text{ FT}^2}{2.32 \text{ FT}^2/\text{GAL}} = 19 \text{ GAL}$
V = 20 GAL	ACTUAL COVERAGE 5.5 #/FT <sup>2</sup>
AREA B <sub>1</sub> = $\frac{.785(16^2 - 7.5^2)}{n} = \frac{(256 - 56) .785}{n} = \frac{157}{n}$	
n = 7      A = 22.4      V = 10 GAL	ACTUAL COVERAGE 5.4 #/FT <sup>2</sup>
AREA C <sub>1</sub> = $\frac{.785(625 - 256)}{n} = \frac{290}{n}$	
n = 10      A = 29      V = 10 GAL	ACTUAL COVERAGE 4.2 #/FT <sup>2</sup>
AREA D <sub>1</sub> = $\frac{.785(1225 - 625)}{n} = \frac{470}{n}$	
n = 12      A = 39      V = 10 GAL	ACTUAL COVERAGE 3.2 #/FT <sup>2</sup>

Figure 141. Program for Material Application Control Typical Site - 70-ft Diameter



AREA A<sub>1</sub> =  $\frac{\pi 8^2}{6} = 33.6 \text{ FT}^2$  OR 14.4 GAL  $V_A = 15 \text{ GAL FOR } 5.4 \text{ \#}/\text{FT}^2$

AREA B<sub>1</sub> =  $\frac{\pi 18^2 - \pi 8^2}{6n} = \frac{\pi}{6n} (18^2 - 8^2) = \frac{\pi}{24} (18^2 - 8^2) = 34.1$   
 $n = 4$        $A_{B_1} = 34.1$        $V_{B_1} = 15 \text{ GAL FOR } 5.3 \text{ \#}/\text{FT}^2$

AREA C<sub>1</sub> =  $\frac{\pi}{6n} (28^2 - 18^2) = \frac{\pi}{6n} (784 - 324) = \frac{241}{n}$   
 $n = 8$        $A_{C_1} = 30.125 \text{ FT}^2$        $\frac{30.1 \text{ FT}^2}{2.9 \text{ FT}^2/\text{GAL}}$   
 $V_{C_1} = 10 \text{ GAL FOR } 4.1 \text{ \#}/\text{FT}^2$

AREA D<sub>1</sub> =  $\frac{\pi}{6n} (34^2 - 28^2) = \frac{\pi}{6n} (1156 - 784) = \frac{\pi}{6n} (372) = \frac{195}{n}$   
 $n = 5$        $A_{D_1} = 39$        $V = 10 \text{ GAL FOR } 3.2 \text{ \#}/\text{FT}^2$

Figure 142. Program for Material Application Control Typical Site - 68-ft Diameter

## (2) Fabrication

Fabrication is begun by applying a swirl pattern of fiberglass roving on the ground. This is applied in a manner such that one layer provides sufficient reinforcement for one pound of area density total resin-glass weight. This amount is best described as a thin veil through which the ground can barely be seen. The resin is applied immediately following the spraying of the glass.

The quantity of resin is monitored by the equipment operator who relays this information to the resin spray operator. Additional layers of glass are applied and wet with resin until the desired area density is obtained. A small portion of resin is conserved for use "touching up" exceptionally troublesome spots such as weeds, stiff glass clumps, etc. It is advantageous whenever possible to apply the resin spray from diametrically opposite directions on alternate passes. Figure 143 depicts a typical combined spray operation.

Two basic techniques have been explored. One technique provides application of the full density material at one time. An alternate method is to apply approximately one half the material and allow this layer to gel. The remainder of the material is then applied over the gelled layer. This latter technique is useful in preventing run-through of the resin material, but may contribute to unevenness in the finished site.

## (3) Personnel Requirements

The minimum personnel required for site fabrication are as follows:

- (a) Equipment operator
- (b) Resin spray operator
- (c) Glass spray operator.

However, in order to fabricate a large (50- to 70-foot diameter) site in a reasonable time (3 to 5 hours) additional personnel are required. These include one additional resin and glass spray operator and one to two equipment service operators.

The equipment operator (1) actuates the pump controls and (2) monitors and regulates the flow of resin, catalyst and air to the respective guns. (Note: Detail operation was described in references 3 and 4.)

The resin spray operator and glass spray operator work in conjunction to spray a relatively uniform fiberglass reinforced plastic mat over the prescribed site area.

The equipment service operator (1) changes glass spools as they are depleted and (2) corrects any malfunctions which may occur in the glass spray system. This function may be performed by the glass spray operator on small sites but assistance of the additional personnel is required for large scale sites.

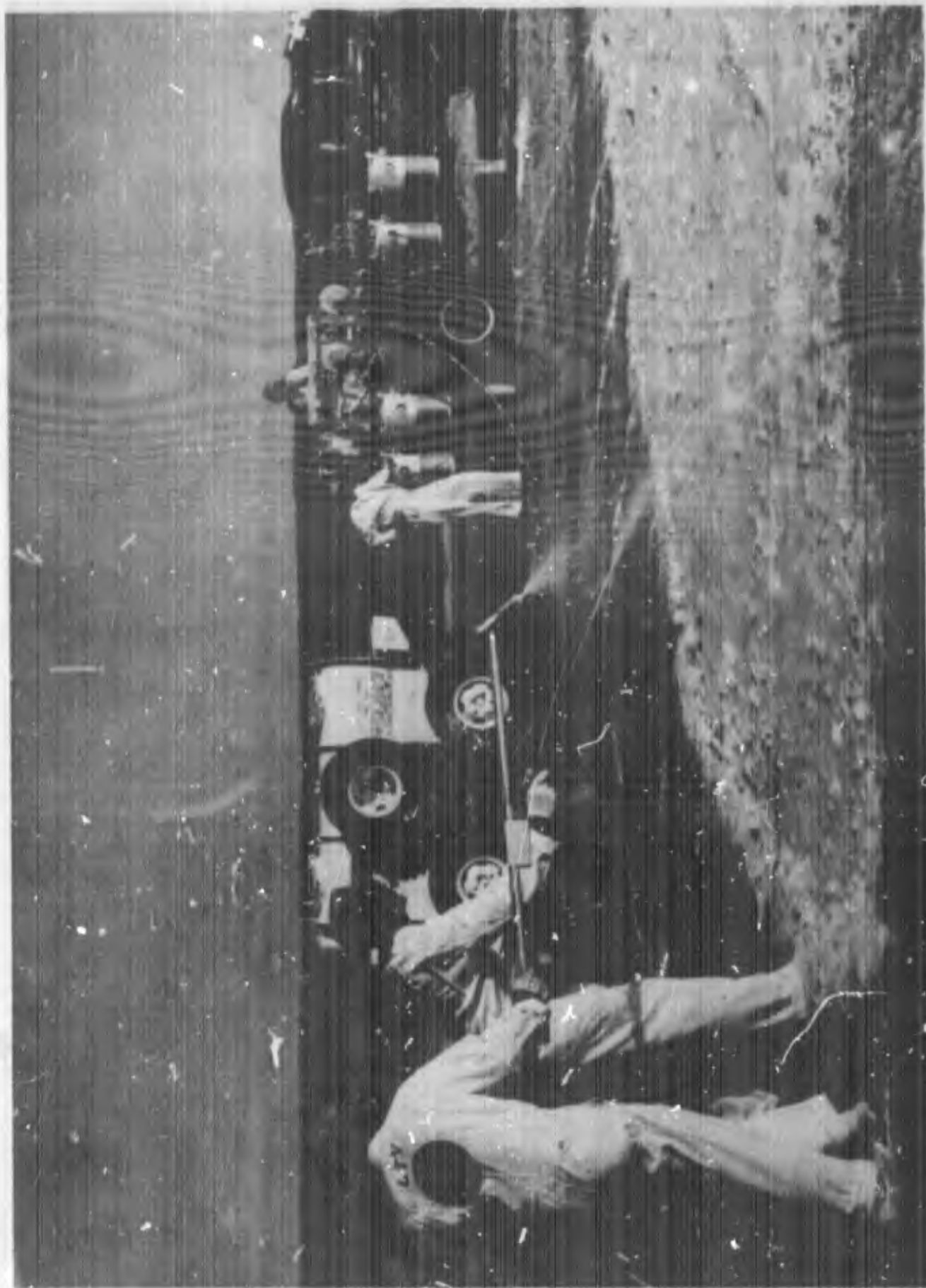


Figure 142. Combined Resin and Glass Fiber Spray Operation

Miscellaneous functions such as relocation of equipment, change out of resin hoses, etc. are shared by the crew. Reference (3). Preliminary Equipment Operation Instructions, contains detailed field operational procedures.

## 2. REMOTE SITE TESTS

### a. Summary

Full scale remote field sites were prepared and tested to determine operational problems and to establish feasibility of the overall system concept. These sites were prepared in Europe in order to utilize existing turbojet VTOL fighter class aircraft currently flying. Two sites were prepared for the P.1127 aircraft in England and one site was prepared for the VJ101C-X2 aircraft in Germany during the 1 September through 15 October 1965 period.

The Kestrel Tripartite Evaluation Squadron based at the West Raynham Royal Air Force Base successfully operated the P.1127 aircraft from both a 66-foot diameter site and from a 50-foot diameter site. The German site was approximately 60 x 65 feet in size at the Manching Air Base. This site successfully withstood the initial 40-second hover flight of the VJ101C-X2 aircraft at a 14-foot altitude. On the second test the edge of the site lifted due to flight procedure. Further tests were therefore cancelled.

Photographic and downwash velocity-temperature data were obtained from the 66-foot diameter English site and the German site.

### b. Application Equipment Shipment

The application equipment, consisting of the WM-300 truck and four tank trailers described in Section III was skid-mounted and air-shipped to the Bircham Newton Royal Air Force Base near Fakenham, England and trans-shipped to Manching, Germany. All necessary support equipment and spares required for remote operations were transported.

### c. Materials Shipment

The Rapid Site resin mixture was air-transported to England in standard closed top 55-gallon drums and transferred to the tank trailers for movement to the site. The methyl-ethyl ketone peroxide catalyst was obtained locally, surface shipped in 40-pound containers or air-shipped in small one-pound containers. Solvent was obtained locally. The fiber-glass roving was shipped in 30-pound cartons which could be loaded directly into the glass spray apparatus.

Results of the remote tests indicated that further improvements were required in the following areas:

- . Elimination of material shrinkage and resultant cracking.
- . Minimization of downwash-induced erosion effects at the edge of the site.
- . Equipment designed for rapid and easy site fabrication.

3. REMOTE SITE FABRICATION-ENGLAND

a. Site Selection and Preparation, Site No. 1 - England

An unused grass field aerodrome was selected as the location for the first site to be prepared for the P.1127 aircraft. The surface was level and all approaches were clear of obstruction. Soils data was gathered for the area and summarized in Table X. Cone penetrometer readings indicated California Bearing Ratios above 4.5 (Core Index of about 190) from the surface down to about 12 inches depth; specifically, 4.5 at 3 inches, 7.5 at 6 inches and 12.0 to 14.0 at 12 inches. Moisture content was 16.6% by weight. The site was uncultivated and covered with a high grade turf. Various types of grasses (grown to a height of approximately 30 inches) covered the site and had produced at least two inches of dense, wiry root system. From the surface downward, bore-hole samples produced about one foot depth of topsoil, followed by about two feet of sand-gravel-flint material. Prior to fabrication the 66-foot diameter site was mowed to a nominal 2-inch grass height and loose grass was removed. The site was laid out utilizing a chalk line marker in preparation for the actual spraying operation. No further site preparation was required.

b. Site Fabrication

The site was fabricated to a diameter of 66 feet using the basic site fabrication techniques described above. The site was fabricated starting at the center and completing one semicircular half at a time applying the full resin and glass reinforcement quantities to produce the required total thickness. Figure 143 illustrates the various sectors and the densities achieved. A total of 1439 gallons of resin and 1000 pounds of fiberglass was applied producing a site with a density of 5.5 lb/ft<sup>2</sup> at the center and tapering to 4.00 lb/ft<sup>2</sup> at the edge. The total site weight was approximately 17,000 pounds. The edge was fabricated by pressing a slot into the soil approximately 1 inch wide and 4 inches deep and filling with the resin glass mixture. The slot was formed by attaching a special steel wheel to the rear wheel of the prime mover and driving around the periphery of the site. The chronological sequence of events for site fabrication are shown as follows:

17 September 1965

Time

0801

1st 2 trailers arrived on site

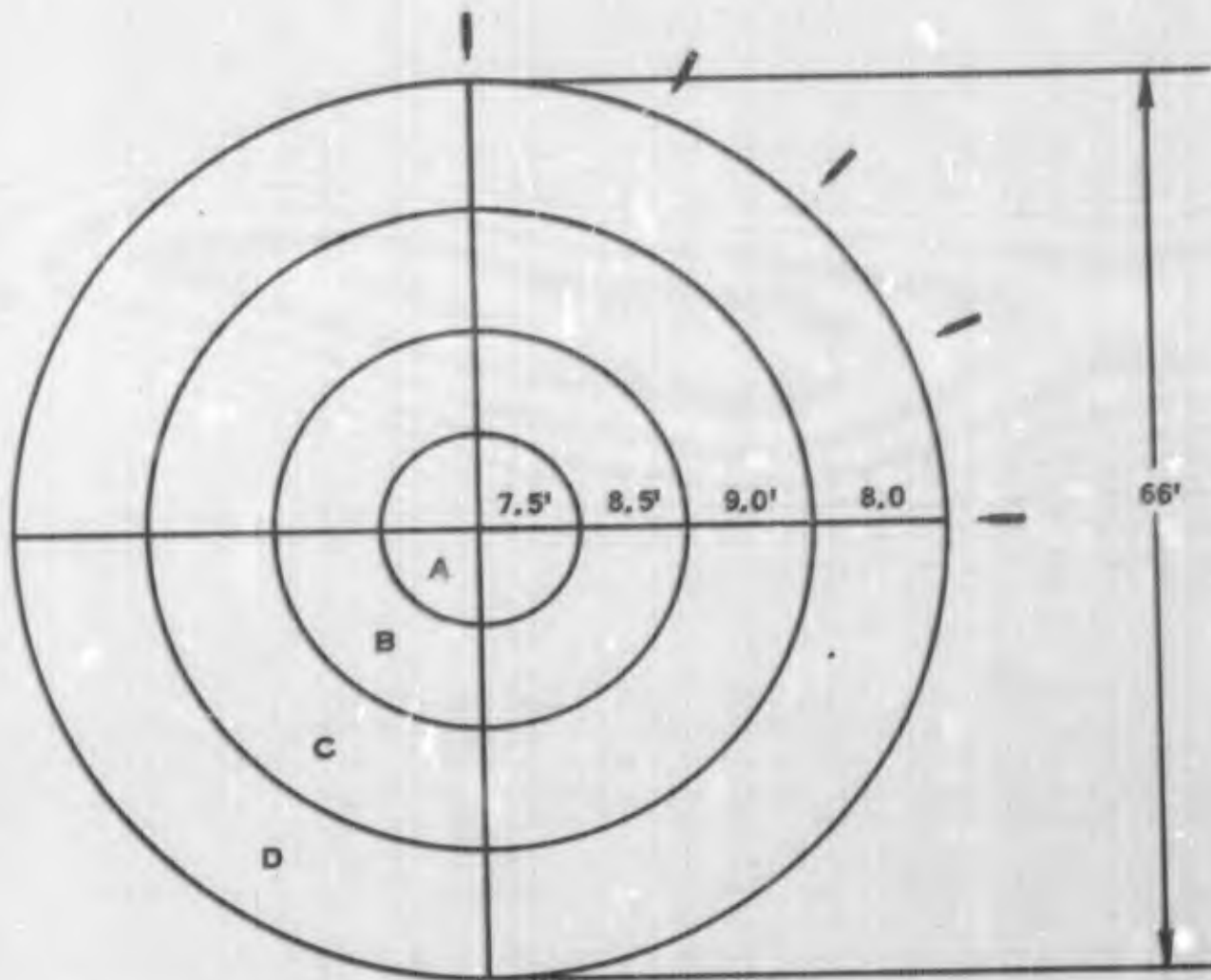
Table X  
SOIL DATA SITE NO. 1 BIRCHAM-NEWTON

CBR AND CI READINGS BY MECO PENETROMETER								
POINT	CBR - DEPTH				CI - DEPTH			
	3"	6"	9"	12"	3"	6"	9"	12"
1	4 1/2	6	8	11	190	290	--	--
2	5	7	9	14	200	290	--	--
3	4 1/2	8	11	12	210	290	--	--
4	6	7	8	14	200	290	--	--
5	5	6	8	12	200	290	--	--
6	4 1/2	5	9	14	210	290	--	--
7	5	6	11	14	190	290	--	--
8	6	6	10	14	180	290	--	--
9	4 1/2	7	9	12	210	290	--	--
10	5	6	8	14	200	290	--	--

**NOTE:**                    **SITE AND GROUND CONDITIONS**

1) Moisture Content = 16.6%

2) Heavy rooted turf 4-inches to 12-inches high - assorted types of grass - mowed 1/2-inch high prior to preparing site.



**AREA COVERED**

- AREA A — 5.25 LB/FT<sup>2</sup>
- AREA B — 5.17 LB/FT<sup>2</sup>
- AREA C — 4.00 LB/FT<sup>2</sup>
- AREA D — 4.00 LB/FT<sup>2</sup>

Figure 144. Site No. 1 P.1127 Site Layout Birchem-Newton Airfield, England Prepared 17 September 1965

0809	2nd 2 trailers arrived on site
0833	Spraying of fiberglass commenced
0835	Spraying of resin commenced
1050	1st half pad completed
1100	Truck moved
1118	Truck relocated and spraying restarted
1312	Pad completed
1335	2 trailers removed from site
1342	Last 2 trailers removed from site
1345	Site cleared and declared operational

The pad was completely sprayed in 4 hours 39 minutes. Site preparation required a total of 5 hours 44 minutes beginning with the first resin trailers on site and concluding with removal of all equipment and loose items or debris.

#### c. Flight Operations

First flyby at 45-foot altitude, 30 to 50 knots with the P.1127 aircraft occurred one hour 9 minutes after completion of spraying operations. Two subsequent flyby's were made at altitudes of 40 and 30 feet respectively. Inspection showed an edge crack which was not considered hazardous to further operations. (Figure 145.)

The first vertical landing was made 1-1/2 hours after completion of spraying (see figure 146). A second edge crack was observed at this time (figure 147). After refueling the aircraft on the pad (refueling truck off pad), a vertical take-off was made followed by two more vertical landings and take-offs. A 30-second hover at 15-foot altitude was included in the operations. Operations were secured as the weather began to close in.

No further flights were conducted from this No. 1 site until 21 September due to cracking of the site. One major crack, which originated at the edge of the pad and was discovered during the flyby's, propagated overnight approximately 20 feet toward the center of the pad and was as much as 3/4-inch wide. Numerous other cracks, some hairline, others appearing to extend through the material, were observed. Overspray patches were made on major crack areas and some hand patching was done on 19, 20 and 21 September. No significant re-cracking occurred in patched areas. The sequence of events and timing are shown below.

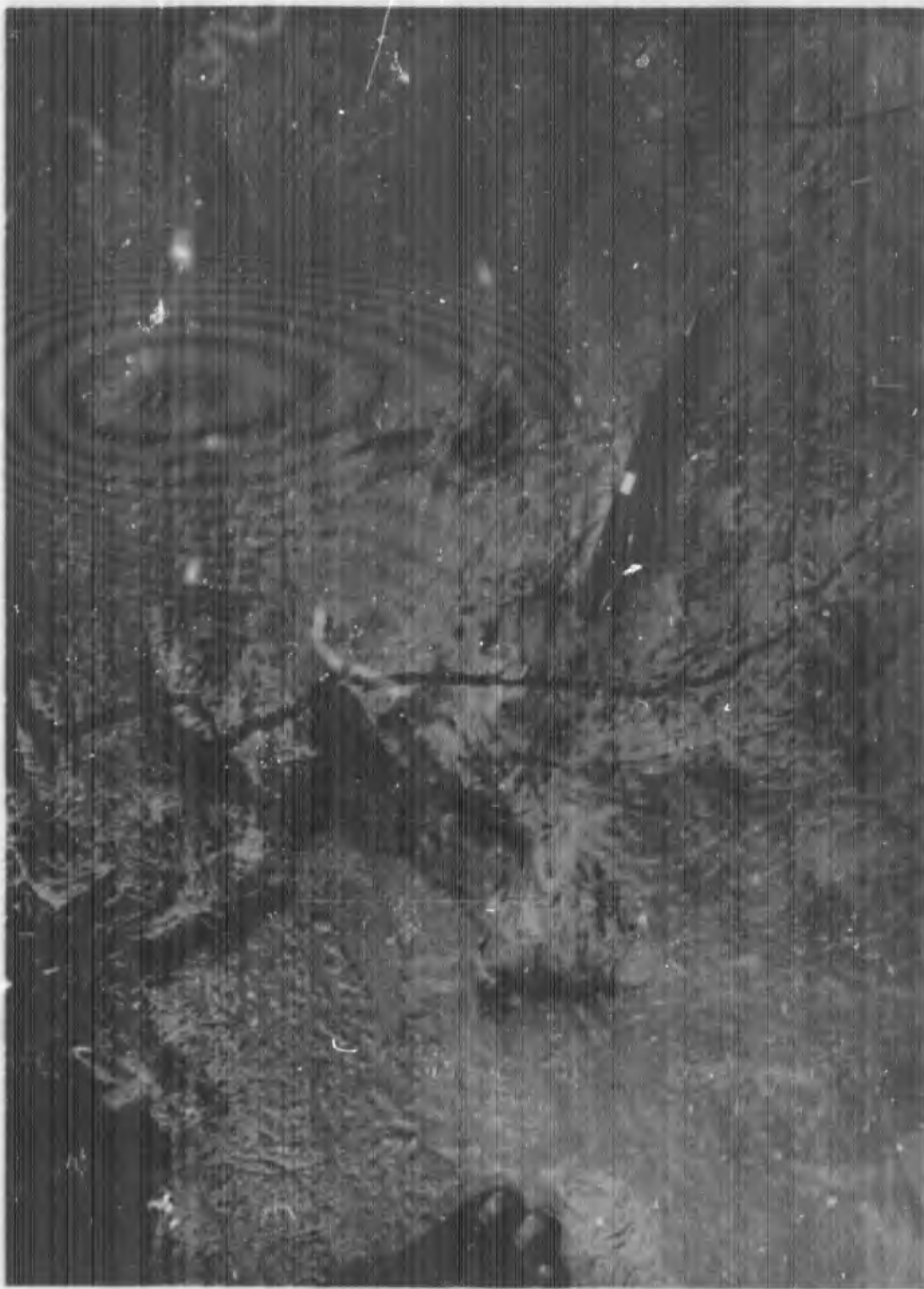


Figure 145. Edge Crack - English Pad No. 1

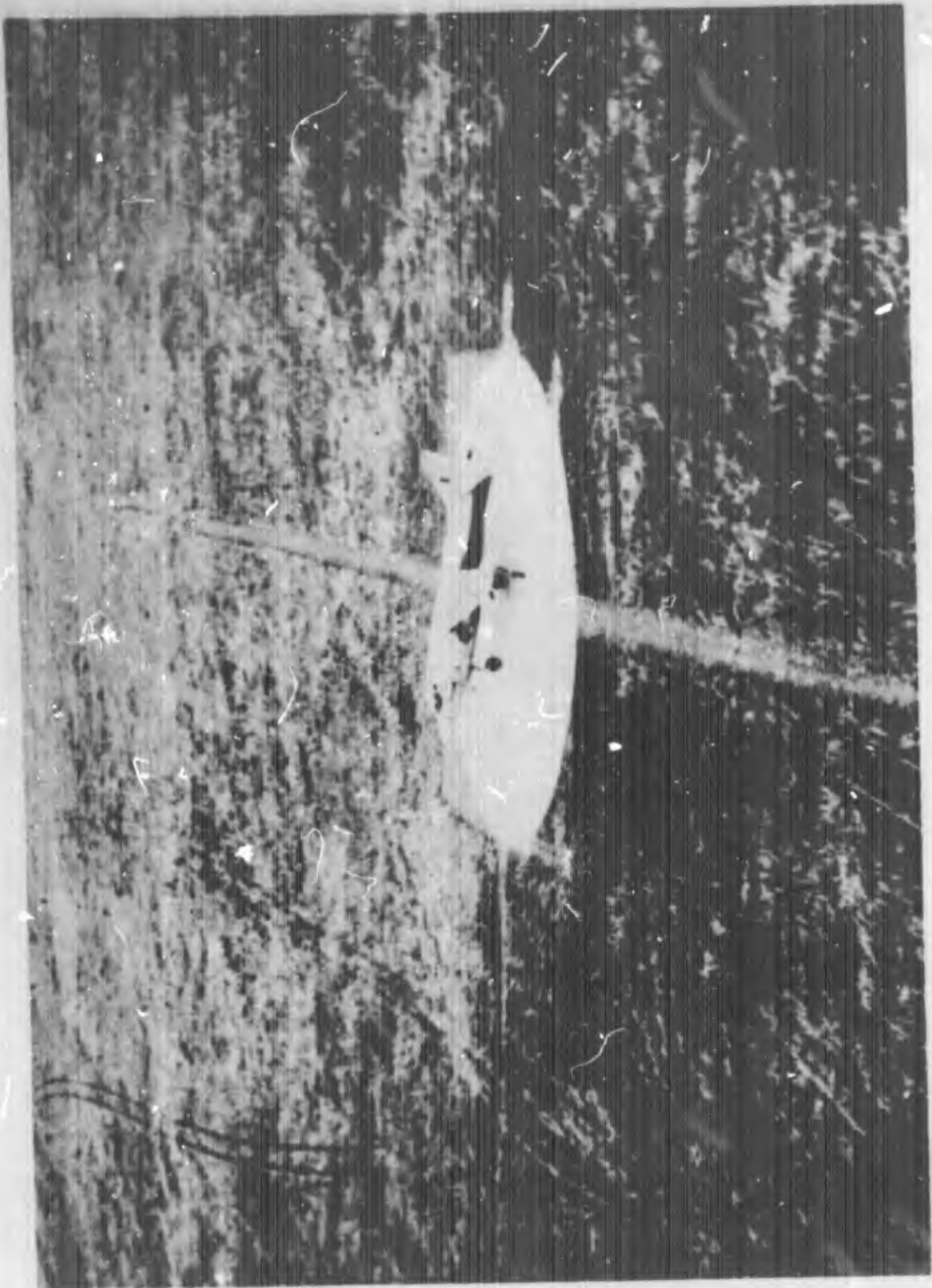


Figure 146. First Vertical Landing of P.1127 1-1/2 Hours After  
Completion of Spraying Operation

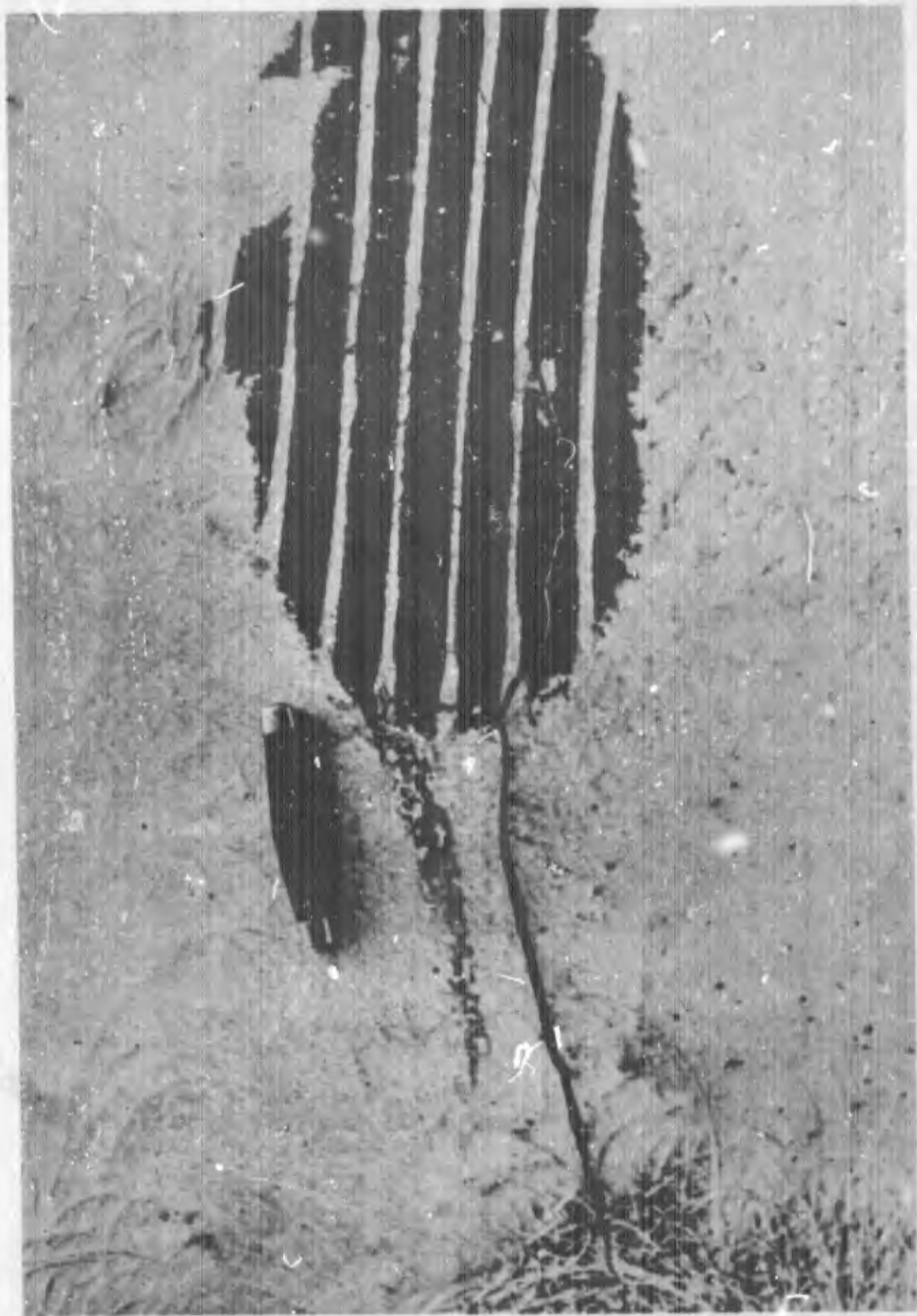


Figure 147. Edge Crack after Vertical Landing - English Pt. 1 No. 1

<u>Time</u>	
1415	P.1127 took off from grass strip
1421	1st flyby at 45 feet altitude 30 to 50 knots
1423	2nd flyby at 40 feet altitude 30 to 50 knots
-	Pad inspection - no defects
1427	3rd flyby - 30 feet altitude - 5 to 10 knots
-	Inspection showed edge crack
1432	1st vertical landing - transition 52 feet
-	Inspection showed 2nd crack
-	Refueled aircraft while on pad
1504	1st vertical take-off - transition 40 feet
1508	2nd vertical landing - transition 32 feet
-	Inspection ok
1510	2nd VTO - transition 55 feet
-	Inspection ok
1513	3rd vertical landing - transition 18 feet - 30 second hover
1516	3rd vertical takeoff - transition 50 feet
-	Inspection - no further defects
	Secured operations

Instrumentation was withheld from this series of tests in order that flight testing might commence as soon as possible after fabrication.

A second series of tests was performed to obtain downwash and temperature data. These tests were performed four days after the first series, following instrumentation installation and site repairs. (A second site was also fabricated during this time period.)

Instrumentation consisting of 5 rakes with 3 pressure pickups and one temperature pickup each were installed on 21 September. Photographic coverage by USAF consisted of two fixed cameras 90° opposed 500 feet from the site and one documentary camera. Three additional vertical landings

and take-offs were made; one of the vertical landings (actually almost STOL) was made extremely low over the edge - 8 feet altitude - with touchdown of the main gear only 6 feet from the edge of the pad. No edge lifting occurred. Little temperature effect was noted - maximum surface temperature as measured by thermo patches being about 450°F.

Chronological sequence of events during the instrumented flights are shown below:

Time

1700	Take off from grass strip
1705	4th vertical landing - hover - 43 seconds at 25 feet
1709	4th vertical take off - 40 feet over edge - 50 feet approach total hover 34 seconds
1713	5th vertical landing - 8 feet hover 5 to 10 seconds - center
-	Refueled
1740	5th vertical take off - 55 feet over edge
1743	6th vertical landing - 8 feet over edge - touchdown 6 feet from edge (extremely low - tail fin only 2 feet off deck)
1746	6th vertical take off - 20 feet over edge

Secured operation

A total of 26 landings and takeoffs (including those above) were made on this site. Further flight operations were discontinued due to additional cracking of the pad. Taxiing operations were made with a fully fueled P.1127 airplane subsequent to this cracking without any apparent effect on the pad or the cracked areas.

d. Pilot's Comments

The following comments were submitted by Major J. K. Campbell, USAF, who flew all test flights on Site No. 1:

(1) When approaching the pad for a decelerating transition and vertical landing, the pad was easy to see in dull or in bright conditions. With 1 to 2 miles visibility in dull weather the pad was seen at about the same time as an adjacent black hangar was seen. With 2 to 3 miles visibility, in bright sunny (but hazy) conditions, the pad was seen sooner than anything else in its vicinity since it acted as a large mirror. This

was not attributed to its pink color so much as its slick reflective surface. If camouflage is considered important, a removable cover should be provided when pad is not in use, or the surface should be "roughed" up in an effort to reduce reflective glare. To the contrary, if camouflage is not important, then the reflective quality is good, as it provides an excellent visual marker at a remote site and is an aid to the pilot.

(a) As the aircraft was transitioned to a hover at 50-foot altitude directly over the pad, the 66-foot diameter pad could not be seen, but the rowed strips (radials) provided necessary visual references for the pilot to initiate vertical descent. From altitudes lower than about 50 feet, no visual reference marks were needed because portions of the edge of the pad could be seen over the sides of the cockpit. Obviously, if smaller pad diameters are used, lower transitioning altitudes will be required or visual references will be required. (See Figure 148).

(3) It was interesting to compare the appearance of the circular (polyester) pad to other square (metal) pads which have been evaluated; specifically, it was much easier to assure good orientation and centering over a circular image than over a square image. This conclusion can be extended to assume that a pilot can center more easily with visual reference to an arc than with reference to two corners, particularly when the pilot must orient an aircraft hot section - rather than his body - over a spot on the pad.

(4) The 66-foot diameter pad size was adequate for takeoff and landing, but not for ground maneuvering.

(5) The prolonged effects of high velocity, high temperature exhaust gases did not have any adverse effects on the pad, except to make large black smoky spots directly under each hot nozzle (see figure 149).

(6) Intencional hovering near the rim of the pad did not lift or break up any portion of the pad. Also, intentional low (wheels at a 3-foot height) and slow (less than 5 knots) landing approach and takeoff climbout did not uproot the edge of the pad.

(7) Landing impact, 1 to 3 feet per second, did not damage the pad.

(8) The braking action (tire to dry surface) was poor; specifically, on polyester the tires slipped at about 40% engine fan speed (1,750 lbs horizontal thrust), while on concrete the tires will hcl d against 60% engine fan speed (3,900 lbs horizontal thrust). The surface was slick to walk around on and felt as if it was coated with talcum powder. In a cross-wind, at vertical lift-off, some sideways slippage occurred - more noticeably than when operating from concrete.

(9) Taxiing onto and off the pad did not cause any additional cracks.

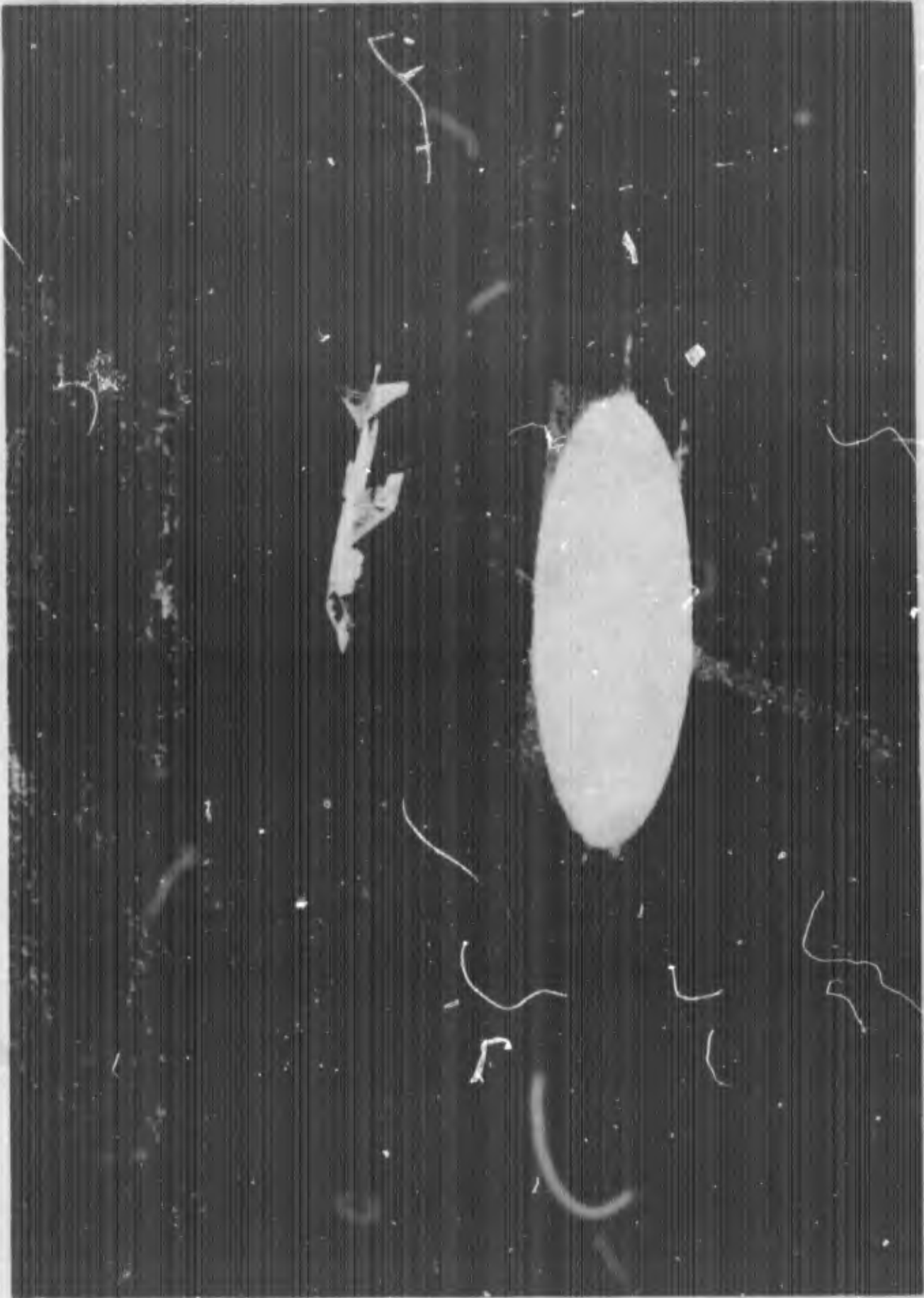


Figure 148. P.1127 Aircraft Hovering Over 56-Foot Diameter Site



Figure 149. Negligible Effects of High Velocity, High Temperature Exhaust Gases Caused by P.1127 on 66-Foot Diameter Pad

e. English Site No. 2

(1) Site Selection

This site was selected primarily to demonstrate the applicability of the sprayed reinforced plastic system to terrain which would be unsuitable for rigid planking. This site was slightly rolling in nature with a shallow ditch running across the area. The site was covered with a grass covering less dense than the first site grown to a height of 3 to 6 inches. The site was mowed to 1- to 2-inch height and sectors marked with chalk line marker. Moisture content was 17.5 percent and CBR ranged from 3 at the surface to 14 at the 12-inch depth. A summary of CBR and CI data is shown in Table XI.

(2) Site Fabrication

The site was fabricated to a diameter of 50 feet with a density of 5.25 lbs/ft<sup>2</sup> at the center tapered to 5.00 lbs/ft<sup>2</sup> at the edge (see Figure 150). The site was poured in quadrants leaving a 1-foot tie section open between each quadrant in an effort to minimize the effects of shrinkage experienced on the first site. These tie strips were joined one hour after the basic site was completed. A chronological sequence of events is shown below:

<u>Time</u>	
0855	Completed edge
0952	Started spraying
1100	1/2 pad completed
1200	Started 2nd half
1310	Small edge crack - 2 hours after section was sprayed
1320	Pad completed except for tie strip
1420	Started tie strips
1502	Completed spraying

The completed site required approximately 979 gallons of material and contained approximately 5-percent glass reinforcement. The total site weight was approximately 12,000 pounds.

No instrumentation was installed on this site although USAF photographic coverage was provided.

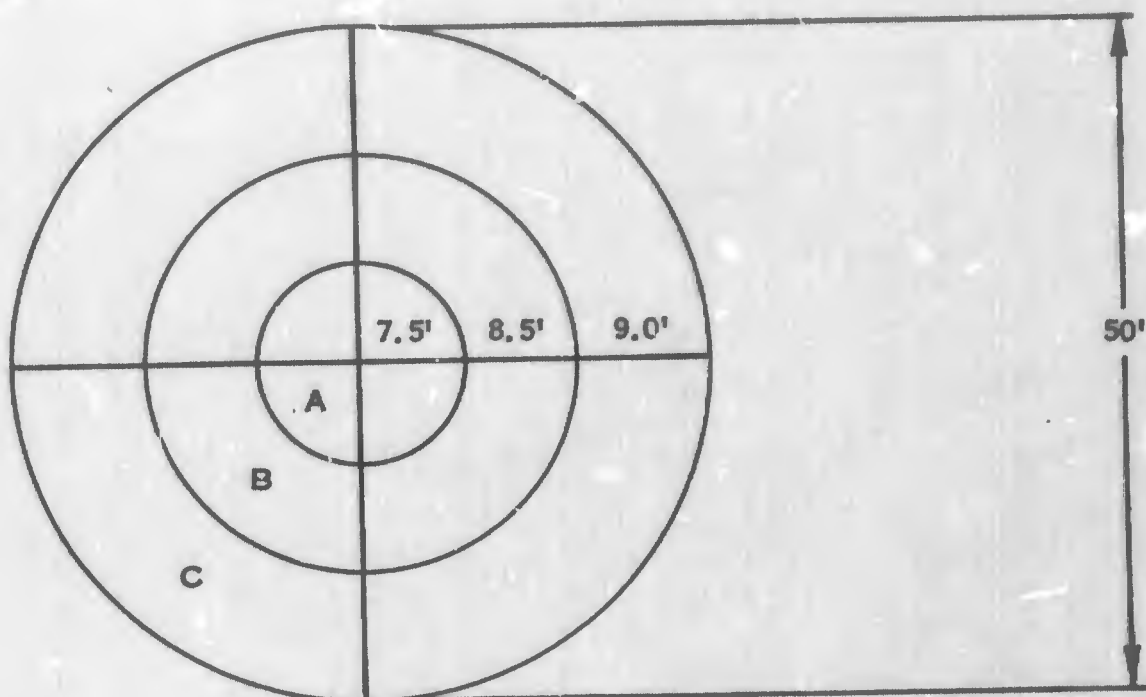
Table XI  
SOIL DATA SITE NO. 2 BIRCHAM-NEWTON

CBR AND CI READINGS BY MEXE PENETROMETER									
CBR - DEPTH					CI - DEPTH				
POINT	3"	6"	9"	12"	3"	6"	9"	12"	
1	3	7	9	14	100	240	290	--	
2	3	7	12	14	180	260	290	--	
3	4	8	14	--	100	290	--	--	
4	3 1/2	7	14	--	120	280	290	--	
5	4	7	9	14	170	240	290	--	
6	3	8	12	14	160	260	290	--	
7	3	7	11	14	110	290	--	--	
8	3 1/2	8	14	--					
9	3 1/2	7	14	--					
10	4	8	13	14					

NOTE:            SITE AND GROUND CONDITIONS

1) Moisture Content = 17.5%

2) Grass covered 3-inches to 6-inches high.



**AREA COVERED**

- AREA A - 5.25 LB/FT<sup>2</sup>
- AREA B - 5.17 LB/FT<sup>2</sup>
- AREA C - 5.00 LB/FT<sup>2</sup>

Figure 150. Site No. 2 P.1127 Site Layout Bircham-Newton Airfield, England Prepared

#### f. Flight Operations

An initial hover/slow flight was conducted at an altitude of 40- to 50-feet approximately 1-1/2 hours after completion of the site. Further operations were discontinued when a surface crack approximately 2 feet long was discovered. This crack was apparently a shrinkage crack and not a result of the hover flight. This area was repaired and flight testing resumed on 22 September when two vertical landings and one vertical takeoff were completed. A chronological sequence of events is shown below:

20 September 1965

##### Time

1625 1st hover - 40 to 50 feet over edge - found crack  
Stopped flights to repair crack

22 September 1965

1104 1st vertical landing - 80 feet over pad  
1114 1st vertical takeoff - 100-foot transition  
1143 2nd vertical landing  
1243 Plane was towed off (Some damage resulted from aircraft wheel loads during towing operation.)  
(See Figure 151)

#### 4. SITE SELECTION AND PREPARATION - GERMANY

The third site was prepared at the EWR-Süd facility at the Ingolstadt/Manching Air Base, Germany. The site selected by EWR personnel was adjacent to the intersection of a concrete taxiway and a ramp area. The site was bare sandy soil with little vegetation to which sand had been applied to a depth of 2 to 3 inches and leveled. CBR readings were not taken in the loose soil. The 60- by 65-foot site was laid out as shown in Figure 152 using a chalk line marker.

##### a. Site Fabrication

A site 60 by 65 feet was laid out (Figure 153) with two perpendicular sides joining the taxiway and runway respectively and a 35-foot radius on the "free" edge. The site was divided into four "quarter" sections leaving an open tie strip between the sections and along the concrete taxiway and runway (see Figure 154). The site was prepared over a period of two days, 9 and 10 October. Approximately 2-1/2 lb/ft<sup>2</sup> was sprayed over the site leaving the tie-strips open, then filling in the tie-strips between the sections and finally overspraying the first half of



Figure 151. Wheel Load Damage - English Pad No. 1

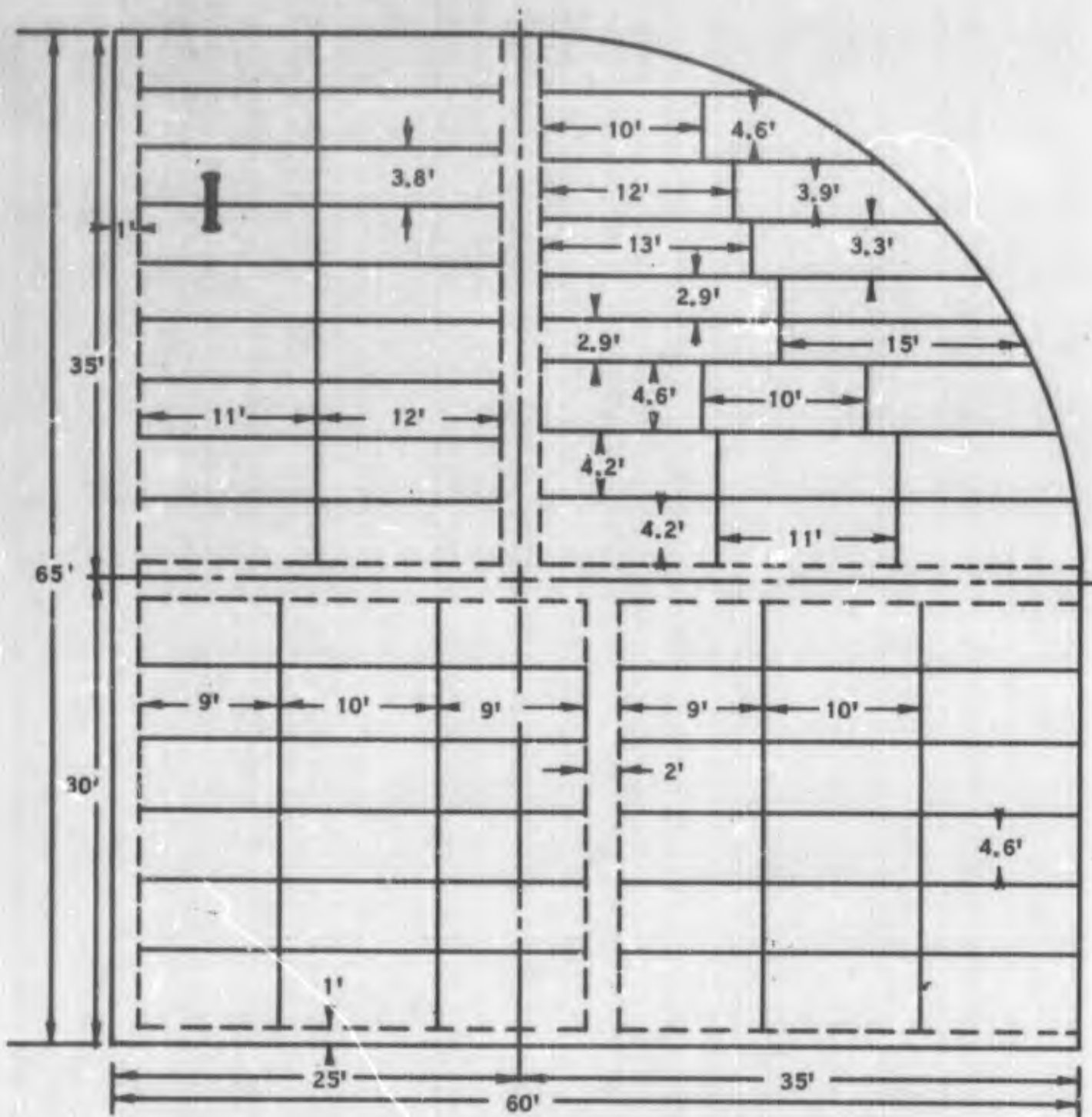


Figure 152. Site No. 3 VJ101C-X2 Site Layout Ingolstadt/Manching Air Base Prepared 9 October 1965

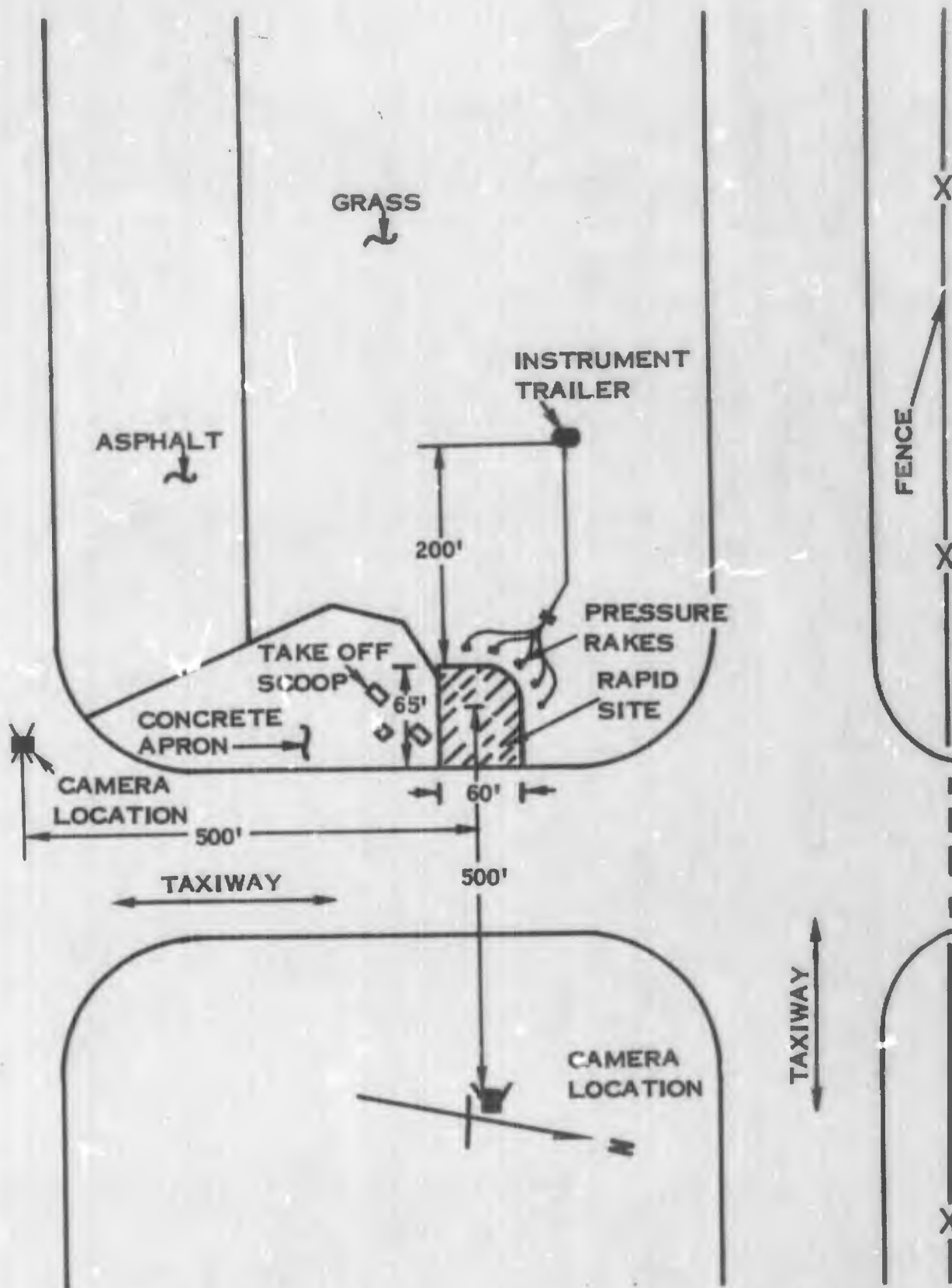


Figure 153. VJ101C-X2 Site Layout, Ingolstadt/Manching Air Base

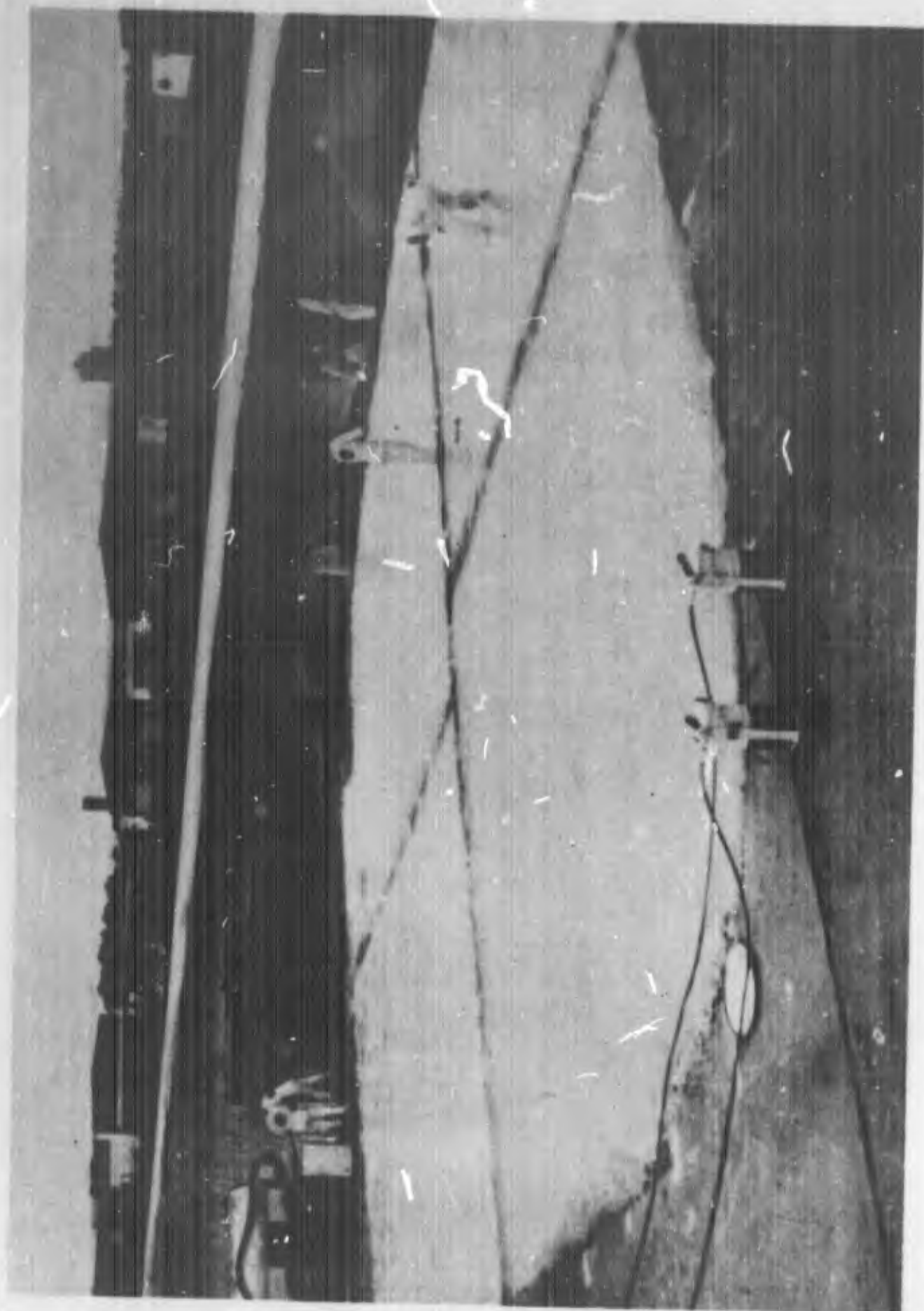


Figure 154. VJ101C-X2 Site Under Construction, Ingolstadt/  
Manching Air Base

the site with another 2-1/2 lb/ft<sup>2</sup> layer. (The strips to the concrete were left open at this time.) Spraying continued until after dark using lights. Time on site 9 October was approximately 7-1/2 hours. Both resin spraying rates, and previously, transfer rates were low. Average temperature during the day was 13°C (55°F); over-night low 6°C (43°F). Table XII contains complete meteorological data.

On 10 October the site was completed by putting down a cookie-cutter edge on the "free" side, completing the tie-strips to the concrete and then overspraying the second half of the pad. About 4-1/2 hours were used to complete the site.

On 11 October cracks in the corner and along taxiway and runway were patched. Instrumentation was installed. On 12 October more cracks were found in the same areas plus a major crack (figure 155) extending across one corner. Bonding to the concrete was such that the surface of the concrete had sheared; in other instances the site material failed. The edge along the runway was sawed free and loose pieces removed as it was apparent that material shrinkage would cause repetitive cracking if further attempts to join to the concrete were made (Figure 156). The large crack was successfully repaired by over-spraying as done in England. The taxiway edge was not sawed loose and provided considerable attachment. Temperature overnight went down to frost with considerable fog.

A total of 1,990 gallons of resin and approximately 1,000 pounds of fiberglass reinforcement were used to complete the site. The total weight of the site was approximately 24,000 pounds. A time sequence of the fabrication operation follows:

9 October

Time

1033	Arrived on site with last 2 trailers
1115	Started spraying
1220	1st trailer used up - changed over to 2nd trailer
1227	Restarted spraying
1230	Finished 1st half - 1st coat 2-1/2 lb/ft <sup>2</sup>
1345	Started 2nd half
1457	Finished 2nd trailer - changed over to 3rd trailer - 2nd half incomplete, lacked 4 sectors on west edge.
1602	Started spraying tie strips - 1st half
1717	3rd trailer used up - changed over to 4th trailer

Table XII  
 AMBIENT WEATHER CONDITIONS SITE NO. 3 MANCHING, GERMANY

Date	Time	Temperature	Pressure	Relative Humidity	
9 October 1965	0000	12°C	730/735 mm	79.5%	
	1000	12°C			
	1200	13°C			
	1400	14°C			
	1600	14°C			
	1800	13°C			
	2300	8°C			
10 October 1965	0000	6°C	730/735 mm	79%	
	1000	11°C			
	1200	11.5°C			
	1400	13°C			
	1600	14°C			
	1800	14°C			
	2000	10°C			
	2400	6°C			
11 October 1965	0000	6.5°C	732/735 mm	66%	
	0600	4°C		70%	
	0800	4°C		70.5%	
	1000	6°C		60.5%	
	1200	15°C		60.5%	
	1400	--		56%	
	1600	16.5°C		51%	
	1800	13.5°C		52%	
	2000	8°C		732 mm	--
	2200	6°C		732 mm	--
2300	--	732 mm	62%		
12 October 1965	0000	5°C	737 mm	--	
	0400	4°C		--	
	0700	2°C		--	
	0800	1°C		76%	
	1000	10°C		--	
	1200	15.5°C		--	
	1400	16.5°C		53%	
	2000	10°C		--	
2200	7°C	70%			

Table XII (Continued)  
 AMBIENT WEATHER CONDITIONS SITE NO. 3 MANCHING, GERMANY

Date	Time	Temperature	Pressure	Relative Humidity
13 October 1965	0000	5.5°C	736 mm	70%
	0300	5°C		--
	0600	3°C		76%
	0800	2°C		--
	1000	--	737 mm	78%
	1200	13°C		64%
	1600	17°C		56%
	2000	--		70%
	2200	5°C	736 mm	73%
14 October 1965	0000	4.5°C		75%
	0300	4.5°C		--
	0600	4.5°C		77%
	0800	5°C	736 mm	--
	1200	8°C		78%
	1300	10°C		78%

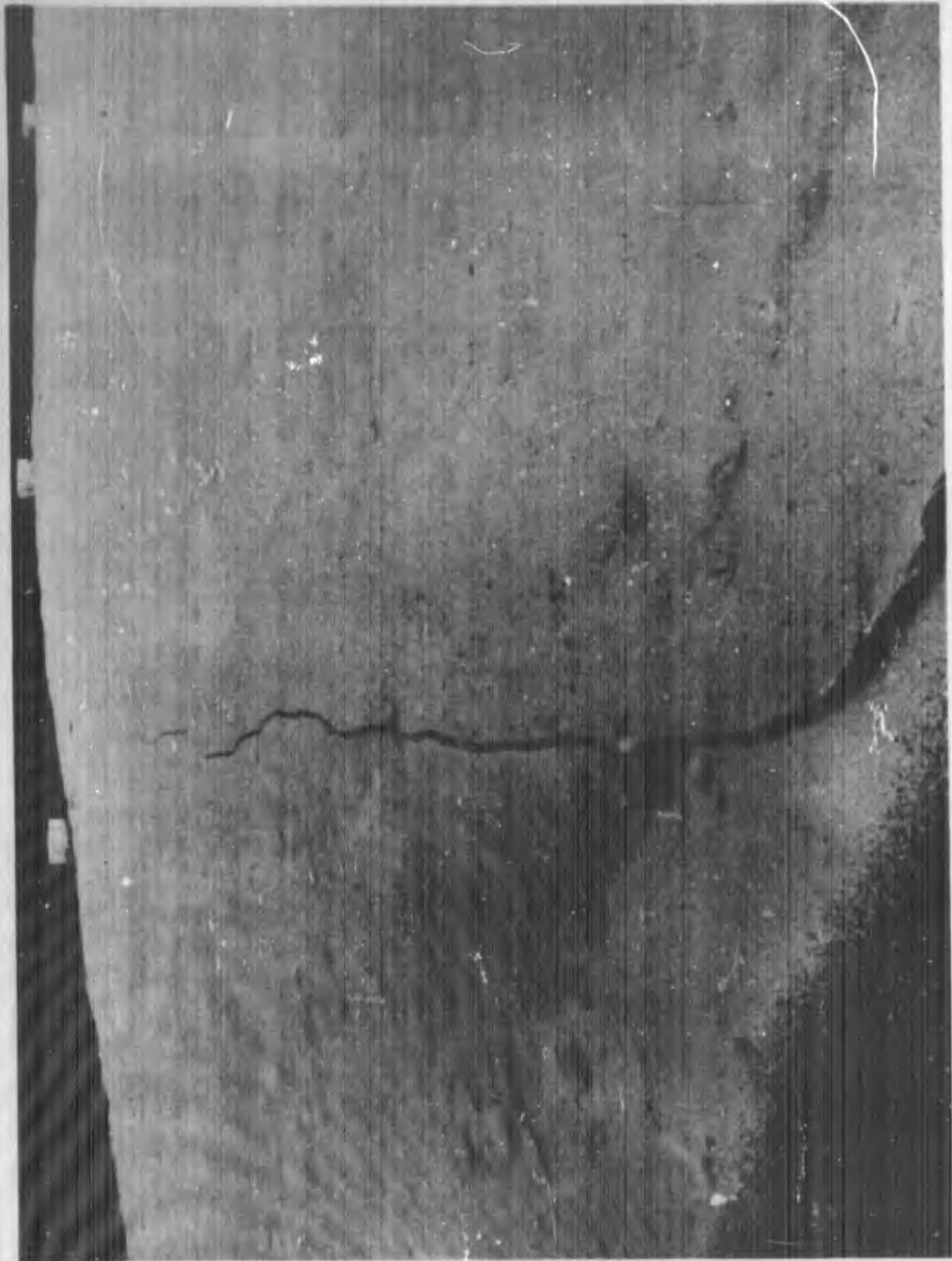


Figure 155. Major Shrinkage Crack - German Pad



Figure 156. Runway Side Crack, German Pad.

1744 1st half - 2nd coat completed  
1813 Started 2nd half tie strip and overcoat  
1819 Tie strip completed - stopped operations  
1830 Large bump or wrinkle appeared in edge of 1st  
half next to taxiway

10 October 1965

1400 Started cookie-cutter edge  
1430 Completed cookie-cutter edge  
1500 Started tie strips to concrete taxiway  
1514 Completed tie strip to taxiway  
1534 Started runway side tie strips  
1618 Started 2nd coat (on 2nd half)  
1717 Found small radial cracks in edge of pad where  
tie in to taxiway and runway was made (corner)  
1801 Completed pad  
1817 Started overspray on corner to patch cracks  
1823 Completed operations

11 October 1965

Found large radial crack in patched area 3 to  
4 feet long in corner adjacent to runway - Also  
some lifting and cracking along runway side due  
to shrinkage and poor bond to concrete due to  
sand or dirt on concrete.

Also crack parallel with taxiway beginning at free  
edge next to taxiway - extended into light cover plate  
area - 6 to 8 feet long.

Patching operations

Instrumentation installed

12 October 1965

Pad developed crack overnight across corner next to underground exhaust system and runway side. Patched this crack by over-spraying. The entire edge along the runway side was sawed loose to relieve further stressing of the pad. The pad was lifted 1 to 2 inches in several areas along this edge.

b. Flight Operations

On 14 October the VJ101C-X2 made a vertical take-off using military power from the runway and made a 40-second hover at a 15-foot altitude after an approach over the edge at a 40-foot altitude (Figure 157). The approach and departure were from the taxiway side of the site that was attached to the concrete. The free corner of the side adjacent to the concrete apron appeared to lift and flutter as the aircraft hovered near by. A landing was made on the taxiway 10 feet from the edge of the pad, and a slight heat discoloration near the edge of the pad was noted.

A second vertical take-off using military power was made from the under-ground deflector installation adjacent to the Rapid Site pad. The agreed flight plan was to approach the site from the side attached to the concrete taxiway. This was not done with the aircraft translating horizontally from the apron side over the pad. This approach flight path exposed the raised free edge of the site, that had previously been sawed loose from the apron to prevent shrinkage stresses (figure 156), to the full downwash velocities as the aircraft approached the edge. With the aircraft at an altitude of approximately 60 feet the downwash entered under the free edge and lifted a large portion of the site 3 to 5 feet into the air. The edge attached to the taxiway remained bonded and the remainder of the site undulated above ground until the aircraft got over the site. The pad remained in one piece and did not break up. The aircraft landed on the taxiway and flight tests were discontinued.

A time sequency of events is as follows:

14 October 1965

1013	Vertical take-off from runway
1015	Hover over pad at 15 feet - time over pad 40 seconds. Came over edge at 40 feet on approach. Corner of pad lifted - leaving pad 15 feet over edge. Touchdown - 10 feet from edge of pad. Slight discoloration of pad near edge. Small standing waves over surface of pad.
1217	Started engines

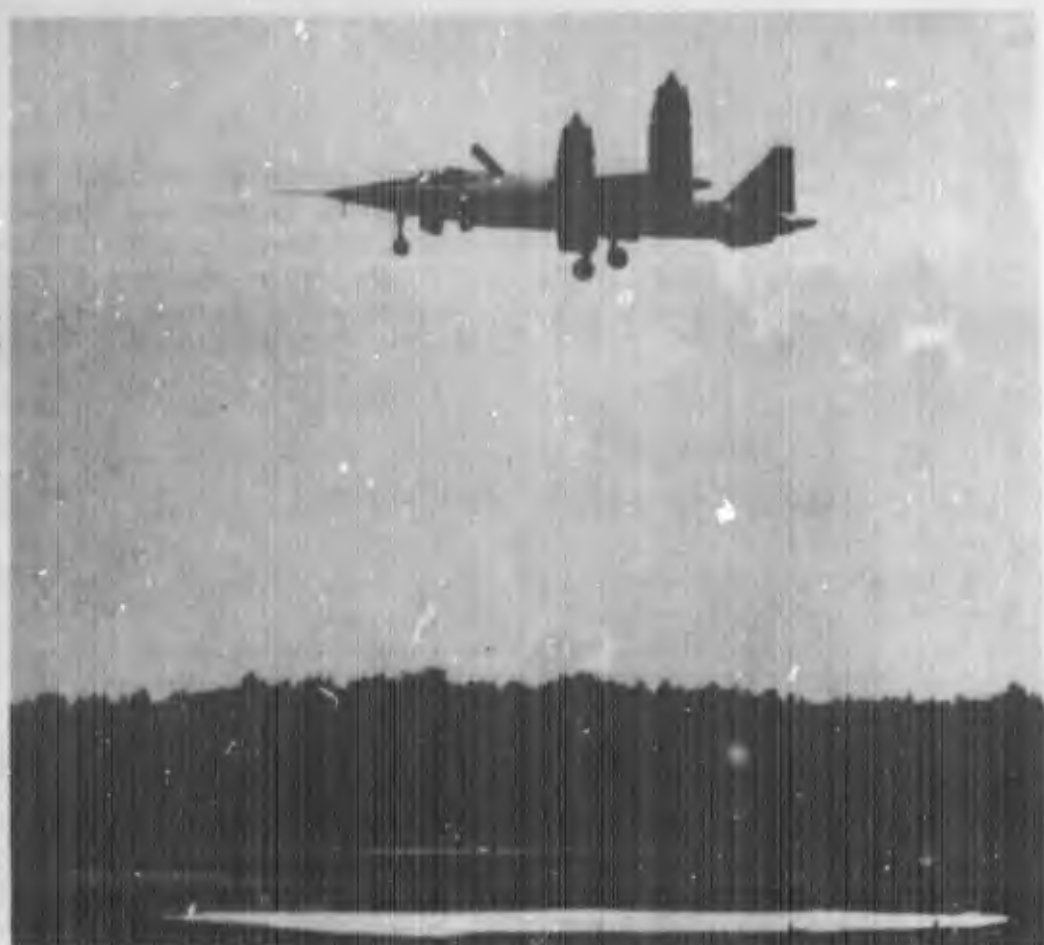


Figure 157. VJ101C-X2 Hovering Over Pad

- 1221 Rotated engines to vertical position
- 1222 Vertical take-off from scoop installation, high above pad - 60 feet - total time on pad 30 seconds, pad lifted 3 to 5 feet. Standing waves over pad. Air exited from underneath pad on opposite side from aircraft.

## 5. SUMMARY OF EQUIPMENT PERFORMANCE

The following observations were made on the performance of the first order application equipment during the preparation of remote sites in England and Germany.

### a. General

The equipment functioned reliably without any significant malfunctions. The pumping rates were low as a result of the low temperatures encountered. There was no delay to site fabrication due to equipment failure.

### b. Truck

The WM-300 Dodge truck performed adequately under all operating conditions. The truck had adequate mobility for all off-road conditions while pulling loaded resin tank trailers. It provided all system power for pumping, mixing, air compressors, and resin transfer without any malfunctions. There was no evidence of engine overheating during stationary operations of five to seven hours. Maintenance was limited to normal vehicle servicing.

### c. Resin System

The experience in both England and Germany indicated that the resin system was incapable of maintaining the design flow rates of 5 gpm and 7 gpm. Ambient temperatures in England were 45° to 70°F, and the maximum pumping rate attainable was 3 to 3.2 gpm in both the 5 gpm and 7 gpm transmission settings. There appeared to be excessive suction losses in the suction manifold to the pumps. In addition, as resin viscosity increased, the output plumbing, flow meters and hoses provided an excessive line drop. As a result, pump output pressures increased to the relief valve setting of 160 psi and flow remained in the 3 gpm range. During transfer from drums to trailer, when short output lines were utilized, the output pressures remained below relief pressure, but flow rates remained low at both 5 gpm and 7 gpm settings, indicating a suction side starvation. Also noted was a definite lagging of the No. 1 pump flow rate compared to the No. 2 pump at all settings. No. 1 pump flow rate would increase when No. 2 pump was shut down. Prior to fabrication of the site in Germany, the truck plumbing was inspected for obstructions and leaks, the pump end-clearances were reset, all belts were tightened, the relief valve pressures were increased to 175 psi, and the inlet screens were removed in an attempt to increase the flow rate. These improvements were offset by a reduction in

ambient temperatures to a daily range of 30°F to 50°F. The flow rates remained for the most part about 3 gpm, dropping as low as 2.5 gpm when temperatures were near freezing. (Note: Actual resin temperatures are not known.) The resin intake and output shutoff gate valves were very slow acting and required excessive time to open and close. The resin flow meters functioned properly throughout the tests and appeared to be accurate. Both the LTV designed pole guns and the FM equipment pole guns were used. The guns were difficult to tune and would not stay in tune as a result of the low resin flow rate and an apparent mismatch of catalyst air to resin flow. These guns had been used in the Dallas trials successfully prior to the European tests. The pole guns, in conjunction with the large resin supply hoses, were difficult to handle, and the strain imposed on the operator over a period of three to five hours was physically exhausting. A swivel joint was badly needed at the gun to prevent hose twist from imposing an additional torsional load to be resisted by the operator. The catalyst hose taped to the resin hose kinked and collapsed on several occasions, causing a reduction in catalyst flow and dropping the gun out of tune. The use of a swivel fitting on the resin hose would assist in keeping both the resin and catalyst hoses straight and out of the operator's way.

#### d. Catalyst System

Total catalyst usage was below that predicted for the English site, even though the flow meter indicated adequate flow. Exact reason for the limited usage was not known. A flow meter calibration was suggested upon return of equipment to LTV.

#### e. Transmission System

The shaft and belt systems functioned adequately. There was no belt breakage experienced. Pump RPM appeared to be correct, but a tachometer was not available and was suggested for incorporation into the Phase I equipment. All belts were readjusted prior to the German site to prevent slippage. The idler installation would not release on the No. 1 pump, and the pump continued to drive, producing up to 60 psi line pressure. The pump brake was inadequate to stop this pump and the resin output valves had to be closed during every shutdown.

#### f. Air Compressor

The air supply was adequate and the compressor functioned without problems. The air produced at the glass pots was extremely wet. The water traps removed large quantities of water from the lines and had to be drained frequently but could not remove sufficient quantities to provide dry air to the pots under extreme moisture conditions. The compressor cycled and unloaded frequently, causing an RPM fluctuation in the pumping system. An engine speed governor would be desirable.

#### g. Glass System

The glass system had frequent malfunctions that added to the crew workload. None of the malfunctions resulted in major delay to the site fabrication, but were a continuing nuisance. The glass guns were improperly heat-treated prior to leaving Dallas, and the valve plugs were scored, resulting in leakage and incomplete cutting of the glass strands. Leakage of the glass pots was minor. The use of the shorter 30-foot hoses and the pots located on the site proved adequate, but required additional labor to move and service the units. Most of the malfunctions were in the gun or were attributable to the wet air supplied to the pots.

#### h. Intercom System

The intercom functioned properly and provided adequate volume control throughout the tests. Because of feedback through the open microphones, the number of headsets was reduced to four. This reduced the overall system noise level, but information needed by the glass operator was lacking since all messages had to be relayed from the resin operator to the glass operator. This situation could have been improved by providing "push-to-talk" switches for the glass operator. Intercom lines to the glass operator would complicate the system because of the dual glass pot arrangement, the location of the pots away from the truck, and the necessity of switching from one pot to the other. The use of a wireless system would present other problems, especially where radio silence is required. Quality of the intercom system was generally low, as purchased, providing problems of shorting, bad connections, cold solder joints, etc.

#### i. Resin Mixers

The air-driven mixers were used to combine the color dye and the promotor with the base resin mixture in the 55-gallon shipping drums. The mixers were not used in the 400-gallon tank trailer. Mixer operation was slow but satisfactory. The mixers were heavy and difficult to move from drum to drum. A portable air-powered lifting dolly would have been useful. The only problem encountered was with the mixer exhaust muffler that iced over during high humidity conditions. This shut down mixer operation but was corrected by removing the mufflers.

#### j. Portable Generator

A 1,200-watt portable generator was used to power instrumentation, and miscellaneous small jobs requiring 115 volts AC. The unit used was marginal and operation was not reliable.

#### k. Power Winch, Prime Mover

Winch operation was satisfactory. It was used frequently to carry resin drums to the site. The winch clutch lever was damaged slightly in shipping and required straightening. An "A" frame or a

powered lifting hoist on the front of the truck could have been used to advantage to lift or move various heavy items of equipment.

#### 1. "Cookie-Cutter" Wheel

The cookie-cutter wheel was used on all three tests. It provided a good clean edge slot on both sites in England but was not quite wide enough to permit proper filling with glass and resin. In soft soils the weight of the truck on the tire next to the cutter wheel tended to press the soil back into the slot behind the cutter wheel. The slot width should remain as small as possible to conserve resin, but a beveled rim should be added at the ground line radius of the cutter to spread or "vee" open the slot to permit entry of resin and glass. This was done by hand in England. The slot was not effective on the German site due to the fact that loose fill dirt and sand sifted back into the slot and the final slot depth was limited to 1 to 2 inches. Additional study will be required to determine the optimum edge treatment desired.

#### m. Tank Trailers

The four 400-gallon tank trailers had excellent drainage and recovery of resin. The hydraulic jacks were used to tilt the trailers toward the drain valve and all but 5 to 10 gallons were recovered from each load. Permanent jacks should be installed on the rear of each trailer to speed the setup time. The trailers were towed at speeds up to 30 mph and trailed the towing vehicle properly. On unprepared ground, only two full trailers were towed at a time, but on surfaced roads, three full trailers and a half-full trailer were towed together. The bumper-hitch structure should be strengthened to permit the towing of all four full trailers. There is a severe downward deflection of the forward axle and spring assembly while stopping due to downward load supplied by the tow bar. This should be strengthened and heavier springs added to the front axle. The trailer brakes had to be disconnected because of improper wiring, aggravating front axle deflection. The tank manhole covers needed better seals. A mastic was used to prevent leakage caused by sloshing of the resin in the tankage during road travel. Filling of the tanks were extremely slow because of the low pumping rate, and on one occasion it was supplemented by lifting drums with a fork lift and pouring the resin into the top of the tank. It is recommended that a supplementary high volume-low pressure pump be considered for the filling operation.

#### n. Shipping Provisions

The wood tank trailer shipping skids were severely damaged during the long distance transport and were generally unsafe. Subsequent shipment should be made with improved skids. Hoisting lugs and appropriate cable slings for hoisting with a crane should be provided for all equipment. Provisions should also be made for fork lift pick up points. Facilities in many areas were very limited, and equipment was not available for handling heavy loads. The trailer skids should be fabricated of steel. A general purpose hoisting sling is required for handling of large equipment boxes. The truck shipping skid will require slight modification to the U-bolt axle attachment to speed loading and unloading of the truck.

## SECTION VI

### LOGISTICS ANALYSIS

#### 1. LOGISTICS SUPPORT CONCEPT EVALUATION

Operational effectiveness of the VTOL rapid site deployment concept is dictated by such parameters as: aircraft performance, operational conditions, enemy air offensive capability, VTOL site preparation techniques, and logistics support requirements. The interrelationships of these parameters are shown in Figure 157. This generalized evaluation model consists of three basic elements: Element A concerns the determination of VTOL site requirements, site locations and site configuration. The operational parameters of interest include: aircraft/mission performance, VTOL downwash characteristics, aircraft-on-site survivability, and logistics support requirements. Element B is designed for evaluating the VTOL rapid site preparation (RSP) techniques. The basic evaluation criteria will be the VTOL pad requirements, site preparation time, required manpower, logistics support requirements, and cost. Element C emphasizes the conceptual analysis of logistics support operations. The scale of comparison will be: mobility, mission time requirement, and operational cost. The required inputs include the deployment concept of RSP operation and means of logistics support. Current studies have been directed to the logistics requirements of RSP spray system, preliminary evaluation of RSP system operational cost, and examination of potential improvement areas where cost reduction is most sensitive. Discussions pertaining to these problem areas are presented in the following paragraphs.

##### a. Logistics Requirements of RSP Spray System

Operational requirements of the RSP spray system can be divided into three categories

- (1) Prior site preparation
- (2) Logistics support
- (3) Site preparation

The prior site preparation responsibilities are to clear the site location by mowing/chopping grass or shrubs, and by removing large loose rocks, and to mark the site for spray operation. The logistics support responsibilities are to deliver RSP equipment and material to the site location, to provide transportation for RSP personnel, and to pick up RSP equipment and unused material from the completed site. The site preparation responsibility is to construct the VTOL pad according to the design specification. Table XIII summarizes the tasks associated with the RSP spray concept, designated responsibilities, required equipment/material and estimated number of personnel required. Table XIV gives the overall dimensions and weight of current RSP spray equipment. The prime mover includes the Dodge power

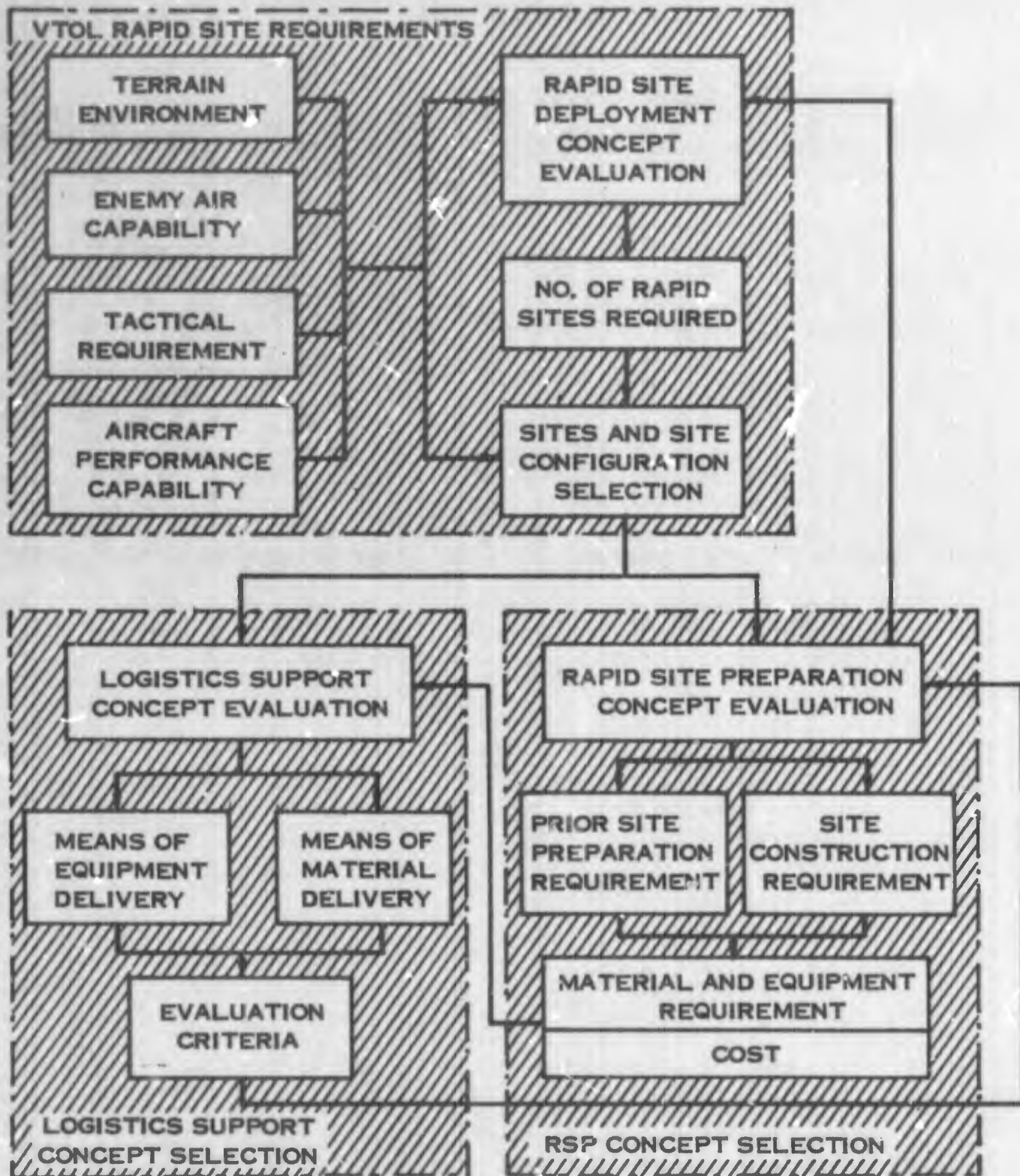


Figure 158. VTOL Rapid Site Deployment Concept Evaluation Model

TABLE XIII OPERATIONAL REQUIREMENT OF RSP SPRAY CONCEPT

Task	Responsibility	Required Equipment	Estimated No. of Personnel Required
Prior Site Preparation	(1) Clear the site location - clear grass & shrubs or loose rocks  (2) Mark the site for RSP	<ul style="list-style-type: none"> <li>. Grass chopper/mower</li> <li>. Hand rakes</li> <li>. Site marker material</li> </ul>	~4 men
Logistics Support	(1) Deliver RSP equipment & material to site  (2) Pick up RSP equipment & material from completed site  (3) Provide transportation for RSP personnel from basing area to site	Air or surface trans- portational vehicles	
Site Preparation	(1) Site construction	RSP equipment and material	~10-14 men

TABLE XIV CURRENT WEIGHTS AND DIMENSIONS OF PHASE I RSP SPRAY EQUIPMENT

ITEM	TANK TRAILER	PRIME MOVER
<b>Dimensions, Overall:</b>		
Length	121" (181" w/towbar)	219 3/16"
Width	74 5/8"	79 1/4"
Height	78 7/8"	78 1/8"
Ground Clearance	13 5/8"	10 5/8"
Wheelbase	60 3/4"	126"
Tread	64 3/4"	64 3/4"
<b>Weights, Pounds:</b>		
Empty	2,250	9,560 <sup>(2)</sup> (1)
<b>Material</b>		
Resin	4,800	---
Catalyst (12 gal.)	---	100
Acetone (18 gal.)	---	108
Gasoline (20 gal.)	---	120
Fiberglass	---	120
Subtotal	4,800	448
<b>Total (with Materials)</b>	<b>7,050</b>	<b>10,008</b>

NOTES:

- (1) Bare truck, prior to modification, 5230 pounds  
 (2) Consists of measured weight of 8,910 pounds plus estimated values for following:
- |                |          |
|----------------|----------|
| Glass Pots (4) | 480 lbs. |
| Hoses          | 120 lbs. |
| Hose Racks     | 50 lbs.  |

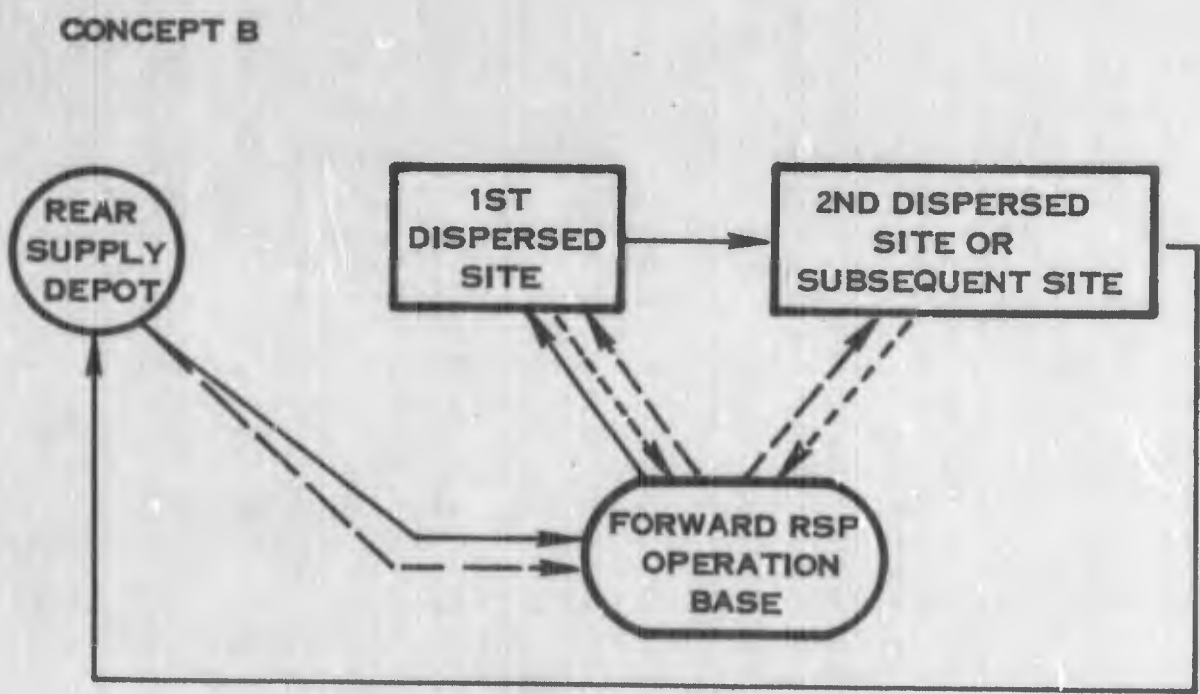
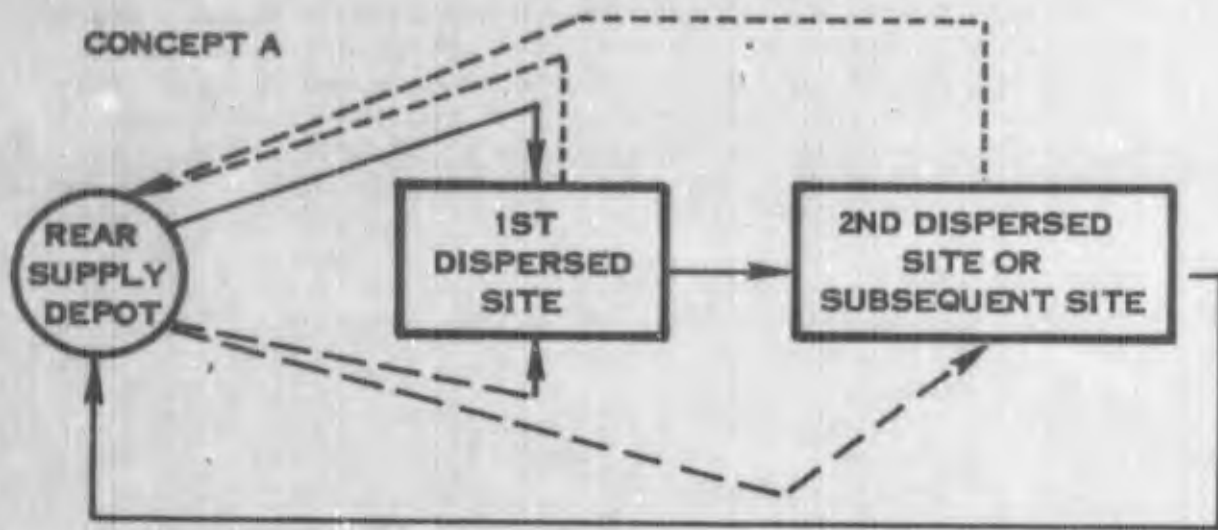
wagon (WM-300), air compressor, resin/catalyst pumps, control panel, fiber glass pressure tanks, hoses, and other miscellaneous items. Since this equipment has been assembled for field test purposes, considerable changes in equipment weight and/or size are to be expected as development proceeds. Because of the inherent advantages of rolling-fluid-transporter (or rolli-tank) over the tank-trailer in transportability, weight saving, and investment cost, the rolli-tank has been selected for use in the current study instead of the tank-trailer.

Since the VTOL pad configuration is determined by the size of the VTOL aircraft, expected wheel loads, downwash characteristics, traffic frequency, and roll-off requirements, the required VTOL pad size and thickness will establish the amount of RSP material needed for VTOL site preparation. For example, a 70-foot diameter pad with a 40-foot basic pad of 5 pounds/square foot and a 15-foot dust cover of 3 pounds/square foot will require approximately 14,700 pounds of polyester-resin-and-fiber-glass, but only 8,000 pounds of the same material will be required if the basic pad and dust cover material is reduced to 3 pounds/square foot and 1.5 pounds/square foot, respectively. In current study, the required RSP material was assumed to be 14,700 pounds per pad, but this requirement was later varied in order to examine its influence on cost sensitivity.

#### b. Preliminary RSP Mission Cost Evaluation

In view of the logistics support responsibilities described in Table XIII, the major task is to utilize the available means of transportation for effective logistics support operations. To achieve this objective, proper design of delivery networks and staging points will be required, so that the necessary number of support personnel, vehicles, and mission time can be minimized. Figure 159 presents two potential logistics support concepts for the VTOL site application. Concept A uses the rear supply depot of the combat area (or area of interest) as an operation base for rapid site preparation. RSP equipment, material and personnel will be transported directly from the rear supply depot to the VTOL site location. Concept B employs the rear supply depot as a staging area but establishes a forward RSP operating base in the vicinity of the proposed VTOL site locations. RSP equipment, material and personnel will be sent from the rear supply depot to this forward RSP operating base and then transferred to the site location. The material routings may be by air, by surface vehicles, or a combination of both. Applying these operational concepts or their variations to the VTOL site deployment model, the operational effectiveness of specified logistics support concepts can be evaluated.

To simulate a VTOL RSP operation, a generalized, dispersed VTOL site deployment model was developed. It was assumed that all dispersed VTOL sites would be selected during peace time or in the early phase of military operations, and these sites would not be prepared until an alert was commenced. Within three days after initial alert, X number of VTOL pads would be prepared, and preparations for X additional VTOL pads scheduled for each day following until the ratio of available VTOL pads



RSP MATERIAL ROUTING - - - - ->  
 RSP EQUIPMENT ROUTING - - - - ->  
 EMPTY RESIN CONTAINERS (TANK-TRUCKS ROLLI-TANKS ROUTING) - - - - ->

ROUTINGS MAY BE BY AIR, BY SURFACE VEHICLES,  
 OR A COMBINATION OF BOTH.

Figure 159. Logistics Support Operation

to occupied pads is four to one. To represent various levels of RSP operations, the total number of prepared VTOL pads under consideration were 24, 48, and 72.

Figure 160 presents the logistics support model chosen for the current investigation. It describes the relative locations of rear supply depot, VTOL dispersed sites, and forward RSP operating base, and shows the routings of RSP equipment and material by means of airborne logistics support vehicles, such as the C-142 or CH-47. The air transportation cost inputs are tabulated in Table XV. Table XVI gives the assumed weight and unit cost of the RSP spray equipment and material. Since the number of sets of RSP spray equipment required to support a RSP operation depends on the required site preparation time, travel time between site locations, available working hours per operational day, and level of RSP activity, the performance capability of RSP equipment will have a direct effect on the cost of the RSP operation. Figure 160 describes the required sets of RSP equipment as a function of RSP system performance capability and the required number of VTOL pads to be prepared in one day. For example, if it is required to prepare 18 VTOL pads in one day, and each set of RSP equipment is capable of producing only two VTOL pads per day, then nine sets of RSP equipment will be required in order to satisfy the mission requirement.

The cost parameters to be examined in current study included:

- (1) Transportation cost for VTOL site preparation equipment and material
- (2) Capital investment
- (3) VTOL site preparation cost

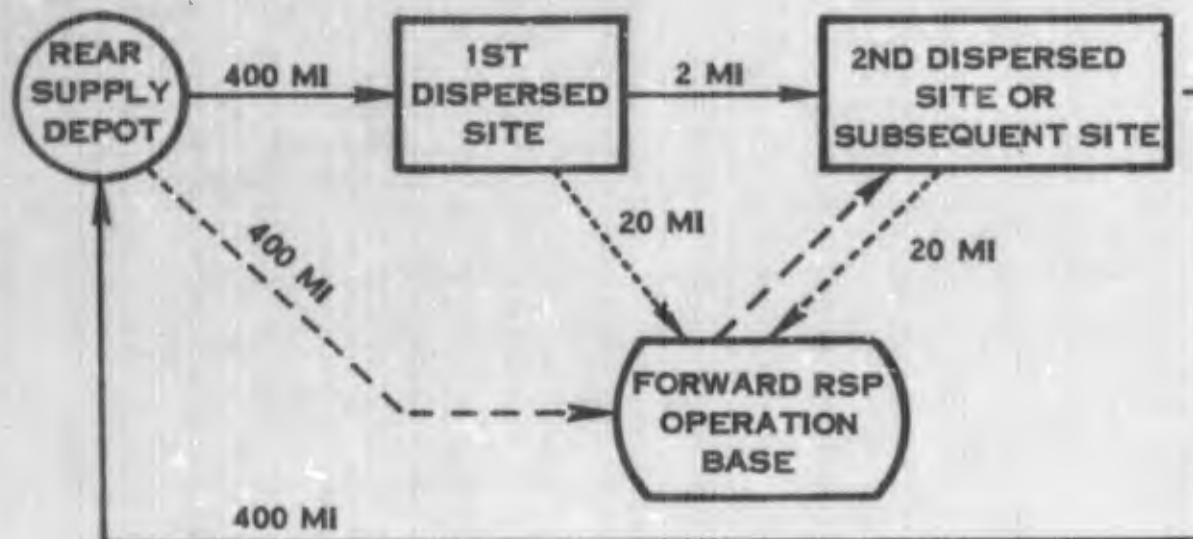
These parameters are described below:

#### Transportation cost

- (a) Transportation cost of the VTOL site preparation equipment and material from the Rear Supply Depot to the Forward RSP Operating Base, or to the VTOL dispersed sites.
- (b) Transportation cost for retrieving the VTOL site preparation equipment and unused material after site completion.

#### Capital investment

- (a) Total cost of VTOL site preparation equipment and material which is necessary to support a specified RSP mission.



RSP MATERIAL ROUTING - - - - ->  
 RSP EQUIPMENT ROUTING - - - - ->  
 EMPTY RESIN CONTAINERS (ROLLI-TANKS) ROUTING - - - - ->

Figure 160. Logistics Support Evaluation Model

TABLE XV ASSUMED AIR TRANSPORTATION COST

From	To	Mean Travel Distance	Air Transportation	
			Typical Carrier	Cost \$/ton-mile
Rear Supply Base	VTOL Dispersed Site	400 mi	C-142	\$1.90
Rear Supply Base	Forward RSP Operation Base	400 mi	C-142	\$1.90
Forward RSP Operation Base	VTOL Dispersed Site	20 mi	CH-47	\$2.86
VTOL Dispersed Site	VTOL Dispersed Site	2 mi	CH-47	\$2.86

TABLE XVI RSP SPRAY SYSTEM INPUT DATA

	Weight	Unit Cost
RSP Equipment	10,000 lb.	\$ 18,131 *
500-gal. rolli-tank	145 lb.	\$ 800
RSP spray material	14,700 lb.	\$ 0.4616/lb.
Container for RSP spray material (55-gal. drum)	80 lb.	---
Resin transfer pump	525 lb.	\$ 1,132

\* Based on 100-unit production cost

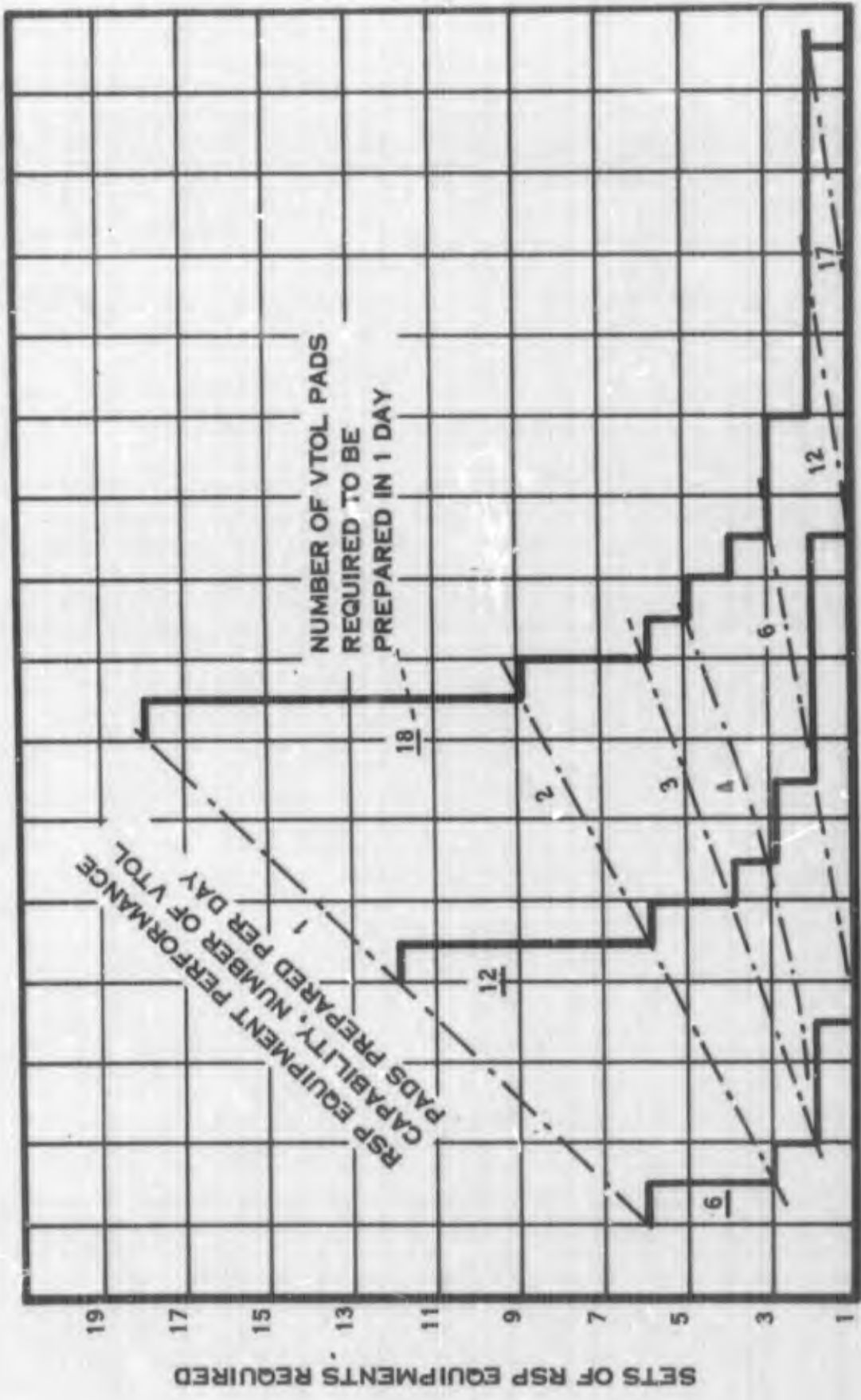


Figure 161. RSP System Requirements

#### VTOL site preparation cost

- (a) Total amortization and maintenance cost for the VTOL site preparation equipment --- assumed to be 2% equipment cost and 4% rolli-tank cost for each prepared VTOL pad.
- (b) Total VTOL site preparation material cost.
- (c) Total VTOL site preparation equipment and material transportation cost.
- (d) Prior site preparation cost and manpower cost (these factors are neglected in current study).

Table XVII gives the typical RSP spray requirement and material which are needed for supporting a specified RSP operation. Based on foregoing assumptions, the mission costs of above RSP system evaluation model is tabulated in Table XVIII.

Examination of other VTOL site materials indicates that the extruded aluminum mats (such as the AM-2 mats or the Dow's MX-18 mats) and the nylon- (or dacron-) neoprene membrane material are potential candidates. The membrane material is limited to the dust cover application because of low structural strength, wear resistance and temperature restriction. The AM-2 mat is 1 1/2 inches by 2 feet by 12 feet in size; weighs approximately 6 pounds per square foot and costs about \$96 per panel. The MX-18 mat weighs 4.7 pounds per square foot and costs about the same as the AM-2 mat. The 2-ply nylon-neoprene (T-17) membrane weighs about 3 pounds per square yard and costs \$5.40 per square yard. Although the cost of T-17 membrane is about the same as the RSP material in dust cover application, the laying of T-17 membrane is much less laborious with associated time saving over the RSP system. However, the technical problems in mating the basic pad resin material to T-17 membrane can be quite difficult and must be solved before the advantages of membrane material can be realized.

The AM-2 mat is designed primarily for use in SATS (short airfield for tactical support) application. The interlocking device enables it to be placed rapidly over a well-graded surface with only a relatively small crew and a few hand-tools. The placement rate of AM-2 mats is about 300 square feet per manhour. To employ the AM-2 mats as VTOL site material, current experience at LTV indicates that the individual mats must be firmly interlocked and edge-protected in order to prevent them from being blown away by the downwash. An incident which illustrates this requirement occurred during the C-142 flight test program at Edwards Air Force Base. The C-142 was hovering at about 30 feet altitude at that time, and a slow turn was executed. During this maneuver, the aircraft translated slightly to a point above the edge of the Convair aluminum matting which formed a section of the runway (see diagram below). After a total of about two minutes in hover, the matting began to undulate and 15 segments, 1 1/4 inches by 4 feet by 4 feet in size and approximately 60 pounds each, broke loose and were blown away. In addition a 210 foot section of the

TABLE XVII RSP SYSTEM MISSION REQUIREMENT

Total No. of VTOL Pads to be Prepared	Sets of RSP Spray Equipment Required	Total No. of Rolli-Tanks Required	Total No. of Resin Transfer Pumps Required	Total RSP Material Required * (tons)
72	6	90	6	529.2
48	4	60	4	352.8
24	2	30	2	176.4

(\* Assumed 14,700 lbs RSP material per pad)

TABLE XV.LII TYPICAL MISSION COST OF RSP SPRAY SYSTEM

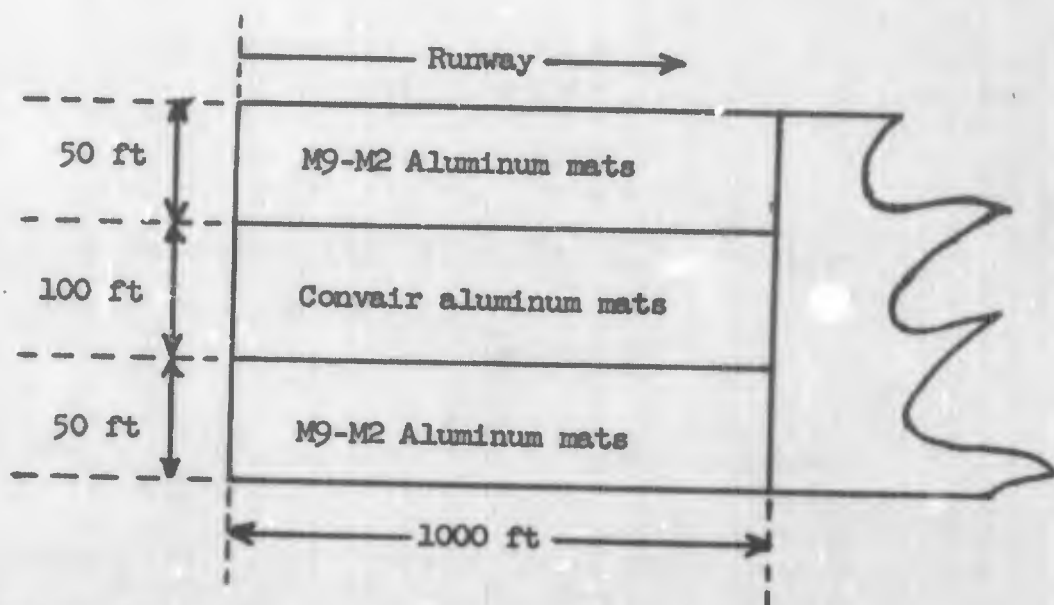
Total No. of VTOL Pads to be Prepared	No. of VTOL Pads to be Prepared per Day	No. of VTOL Pads per Dispersed Site	Total Site Preparation Cost		
			RSP Concept* (1)	AM-2 Aluminum Mat. Concept+ (2)	$\frac{(1)}{(2)} \times 100\%$
72	18	2	\$1,045,322	\$1,848,789	56.5%
48	12	2	\$ 695,170	\$1,232,543	56.4%
24	6	2	\$ 347,583	\$ 616,296	56.4%

Total No. of VTOL Pads to be Prepared	Avg. Site Preparation Cost per Pad		Capital Investment		
	RSP Concept*	Am-2 Aluminum Mat. Concept+	RSP Concept* (1)	Aluminum Mat. Concept+ (2)	$\frac{(1)}{(2)} \times 100\%$
72	\$14,518	\$ 25,678	\$676,136	\$1,148,612	58.9%
48	\$14,483	\$ 25,678	\$450,757	\$ 765,758	58.9%
24	\$14,483	\$ 25,679	\$225,378	\$ 382,854	58.9%

Total No. of VTOL Pads to be Prepared	Avg. Capital Investment per Pad		Total Transportation Cost		Avg. Transportation Cost per Pad		
	RSP Concept*	AM-2 Aluminum Mat. Concept+	RSP Concept*	AM-2 Aluminum Mat. Concept+	RSP Concept* (1)	AM-2 Aluminum Mat. Concept+ (2)	$\frac{(1)}{(2)} \times 100\%$
72	\$9,391	\$15,953	\$522,113	\$700,177	\$ 7,252	\$ 9,725	74.6%
48	\$9,391	\$15,953	\$346,364	\$466,785	\$ 7,216	\$ 9,725	74.2%
24	\$9,391	\$15,952	\$173,181	\$233,392	\$ 7,216	\$ 9,725	74.2%

\* 14,700 lbs. RSP material per pad

+ 70-ft. diameter site



Convair matting runway was lifted by propeller downwash and displaced approximately eight inches laterally.

To prevent such occurrence, the individual aluminum mats will have to be secured with long steel spikes. The required task is laborious and time consuming, especially if the site location is over rocky terrain. This will degrade the placement rate of aluminum mats.

For a first order approximation, the VTOL site preparation cost of RSP system is compared with that of AM-2 concept without the incorporation of prior site preparation cost, manpower cost and the additional cost for sticking down the individual aluminum mats. In reality, these factors will impose larger penalties to the AM-2 concept than to the RSP system. The VTOL site preparation costs of these two concepts are summarized in Table XVIII. The findings indicate that the RSP concept has significant cost advantages over the competitive system under the preceding assumed conditions. For example, the mission costs for the preparation of 72 VTOL pads by these two concepts are listed below:

	①	②	$\frac{\textcircled{1}}{\textcircled{2}} \times 100\%$
	RSP Concept*	AM-2 Aluminum Mat Concept†	
Average Transportation cost per pad	\$7,252	\$9,725	74.6%
Capital Investment per pad	\$9,391	\$15,953	58.9%
Average VTOL Site Preparation Cost per pad	\$14,483	\$25,678	56.5%

(\* Assumed 14,000 pounds RSP material per pad)  
 († Assumed 70-foot diameter pad)

Current investigations at LTV indicate that the required amount of resin material for VTOL pad preparation can be reduced from 5 pounds/square foot to three pounds/square foot for the basic pad, and from three pounds/square foot to 1.5 pounds/square foot for the dust cover, without degrading the pad's usefulness. For a 40-foot diameter basic pad and a 15-foot dust cover, this will result in 46% of material saving, and thus further enhance the competitive position of the RSP System.

### c. RSP System Cost Parameter Sensitivity

To determine the priority of importance for the RSP system improvement programs, the subject study examined the problem areas where the RSP mission cost could best be minimized. This cost sensitivity analysis included the effects of RSP equipment/material weight and RSP material spray rate on the RSP system transportation cost, capital investment and VTOL site preparation cost. The mission ground rules were similar to those presented in above paragraphs. The study findings are presented in Table XIX. Figure 162 provides the graphic presentation of the same cost sensitivity results. As indicated by the plot, the mission cost of RSP system is highly sensitive to the RSP material requirement, but is affected only slightly by the change of equipment weight or RSP material spray rate. For example, a 50% reduction of RSP material can provide a 49.9% reduction in mission transportation cost, a 50% reduction in capital investment, and 48.5% in VTOL site preparation cost; whereas a 50% reduction in equipment weight or a 100% increase in spray rate yields only a 2.2% VTOL site preparation cost reduction. Based on these findings, it is indicative that the improvement of RSP technique in minimizing the resin material requirement should be given top priority in the RSP system improvement program. Current investigations conducted at LTV indicate that the employment of woven fiber glass cloth as basic reinforcement material can provide a satisfactory basic pad with 3 pounds/square foot RSP material and a dust cover of 1.5 pounds/square foot. In comparison with the above 14,700-pound pad (a 40-foot diameter basic pad at five pounds/square foot and a 15-foot dust cover at three pounds/square foot), this reduction of RSP material requirements will result in a 45.6% saving of resin material and a 43% saving of VTOL site preparation cost.

To provide guidelines for RSP material spray rate improvement, Figure 163 relates the time available for spray operation at each VTOL pad location as a function of RSP system performance capability and number of VTOL pads per dispersed site. The travel time between dispersed sites is assumed to be 3/4 hour. The RSP material spray time is assumed to be 80% of the total site preparation time. This time assignment is based on past experience at LTV where a 22,885-pound pad was prepared in five hours and 11 minutes. The actual spray time was four hours and 11 minutes, while the remaining time was for equipment set-up, clean-up, loading, unloading, and other miscellaneous operations. As shown in Figure 163, the available spray time depends on the number of pads to be prepared within specified time interval and number of VTOL pads per dispersed site. For example, if the RSP system has to prepare 4 VTOL pads at two dispersed site locations in 12 hours, then the maximum available

TABLE XIX RSP SPRAY SYSTEM COST PARAMETER SENSITIVITY

Means of Improvement	Comparison Factor	% Cost Reduction			
		72 pads	48 pads	24 pads	
(1) Increase RSP spray rate by 100% with <u>no increase in RSP equipment weight and unit cost</u>	(a) Total pad preparation cost	2.23%	2.23%	2.23%	
	(b) Capital investment cost	8.04%	8.04%	8.04%	
	(c) RSP Equipment Cost	29.0 %	29.0 %	29.0 %	
(2) Reduce the RSP spray equipment weight by 50% with <u>no change in performance and unit cost</u>	(a) Total pad preparation cost	2.22%	2.23%	2.23%	
	(b) Total Transportation cost	4.44%	4.47%	4.47%	
(3) Reduce the required RSP spray material weight by:	(i) 10%	(a) Total pad preparation cost	9.19%	9.13%	9.13%
		(b) Capital investment	7.27%	7.27%	7.27%
		(c) Total transportation cost	8.82%	8.70%	8.70%
	(ii) 20%	(a) Total pad preparation cost	18.37%	18.26%	18.26%
		(b) Capital investment	14.5 %	14.5 %	14.5 %
		(c) Total Transportation cost	17.85%	17.61%	17.61%
	(iii) 50%	(a) Total pad preparation cost	48.5 %	48.6 %	48.6 %
		(b) Capital investment	50 %	50 %	50 %
		(c) Total transportation cost	49.9 %	49.9 %	49.9 %

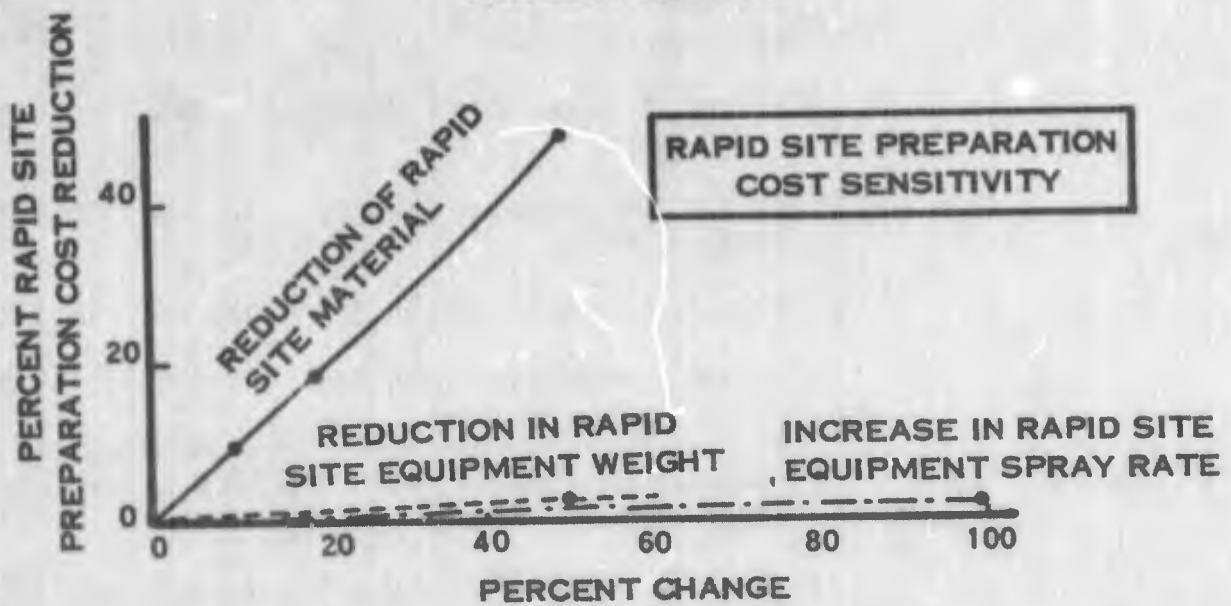
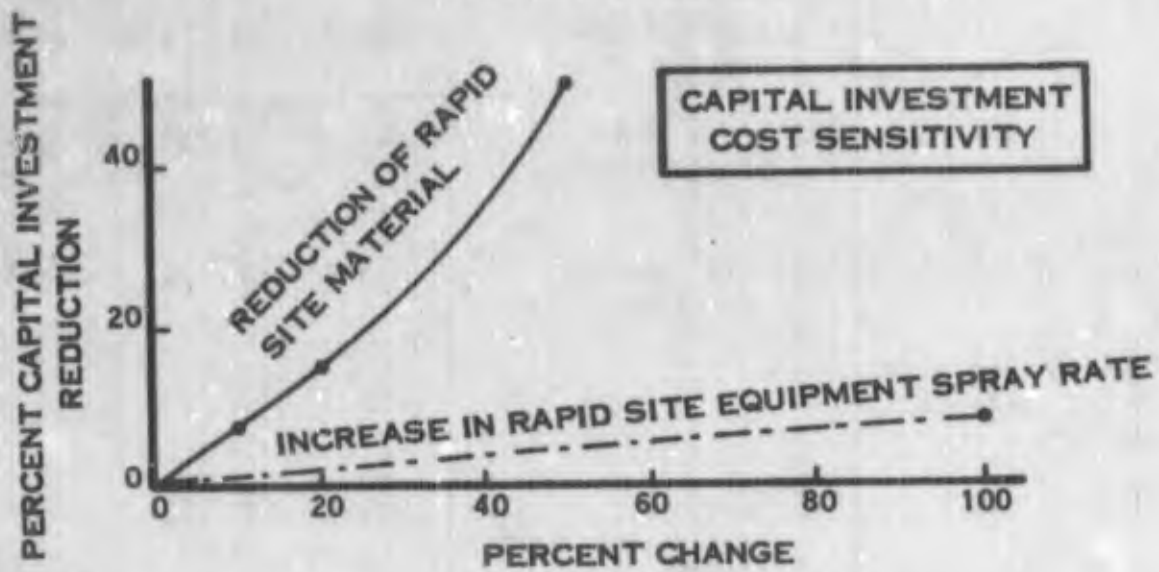
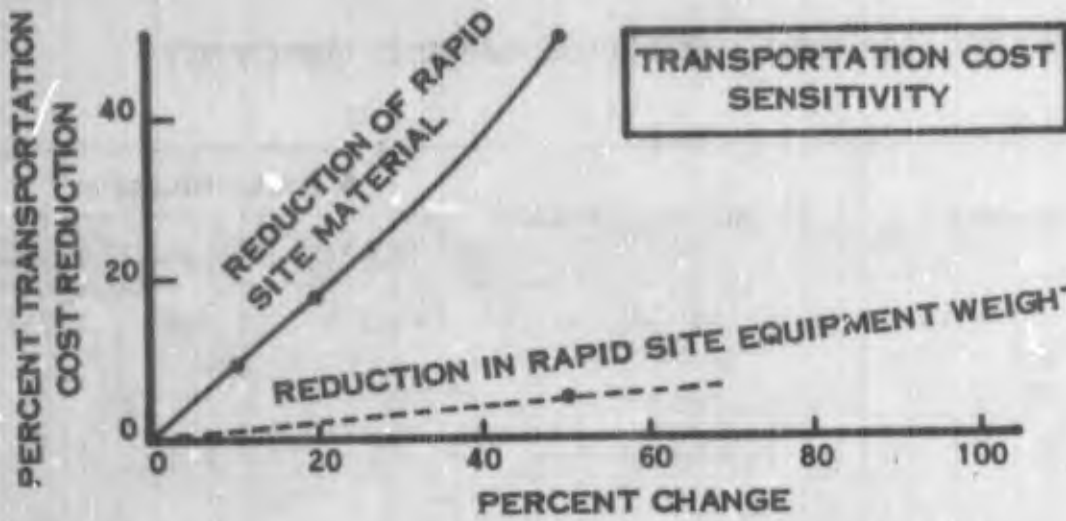


Figure 162. RSP Spray System Cost Parameter Sensitivity

spray time is 135 minutes. However, if the RSP requirement is six pads at three locations in 12 hours, then only 84 minutes per pad is available for spray operation. Consequently, this time constraint defines the minimum spray rate requirement for a specified RSP operation.

Based on the maximum pumping capacity of the current RSP system, the spray time for 14,700 pounds of resin material is 128 minutes. As indicated in Figure 163, this material application rate will enable the RSP system to prepare two 14,700-pound pads at each of two dispersed sites in a total of 12 hours. Any higher VTOL pad preparation requirement will require improved RSP material application technology. This problem area will be examined further during the Phase II program.

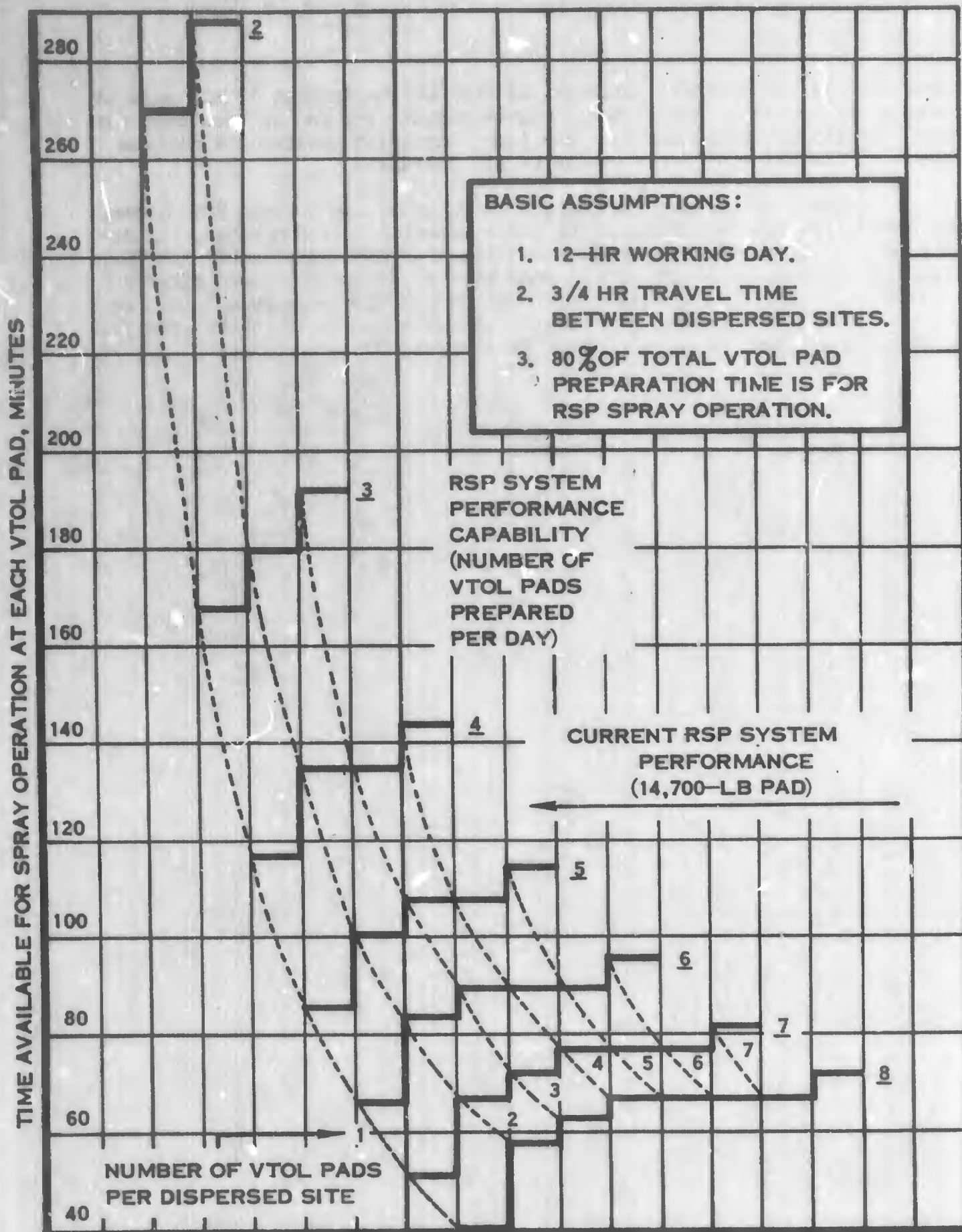


Figure 163. RSP System Generalized Performance Requirement

## SECTION VII

### CONCLUSIONS AND RECOMMENDATIONS

#### 1. CONCLUSIONS

##### a. Material Formulation

A high temperature filled polyester resin (Formulation B-3-B) with good anti-settling properties was successfully produced in large scale quantities. The resin was unaffected by normal handling and shipping by truck, airplane or ship.

Long-term storage (9 months) of the B-3-B resin formulation showed no apparent degradation when stored in sealed 55 gallon drums.

The combination of B-3-B resin formulation and a low percentage fiberglass reinforcement resulted in shrinkage cracks in full scale VTOL sites. Incorporation of a more flexible resin component material reduced the shrinkage of the high temperature resin formulations.

The thermal erosion resistance of an unfilled, fiberglass reinforced, fire retardant resin appears to be adequate for non-afterburning turbojet VTOL aircraft of the P.1127 type.

VTOL sites of increased strength are also obtainable by increasing the percentage of fiberglass reinforcement. The use of woven fiberglass roving in combination with sprayed fiberglass roving gave superior results to sprayed roving only.

A composite pad made by using an unfilled resin as the base layer and a high temperature filled resin as the top layer provided adequate thermal-erosion resistance when exposed to a J85-GE-5 after-burning turbojet engine.

##### b. Application Equipment

The first order application equipment performed reliably during preparation of full scale sites in Europe. Resin spray rates were too low at lower ambient temperatures. Also resin transfer pumping rates were too low for practical field operations.

Many malfunctions were encountered in the fiberglass spraying system. Problems were caused by manufacturing defects, excessive moisture in the air supply and design limitations which necessitated the use of low air pressures. A preliminary design for a higher pressure system was completed.

Hand held spraying systems appear to be of limited usefulness. Remote controls and mechanization of the material application process are required both to speed up the operation as well as to improve the overall uniformity of the remote site. However, hand held systems are needed to provide for repair, touch-up and edge preparation.

c. Site Design Requirements

(1) Site Thickness Criteria

No correlation between CBR and cone index was apparent in defining the load-carrying capability of the soil. On the average, soil deflections were reduced by approximately a factor of twelve for wheel loads applied over 2 to 3 lbs/sq. ft. density pads rather than on bare soil.

The results of the strain gage and deflection data indicate that the stresses on the upper surface of the pad are defined by a combination of plate bending and membrane forces.

The post-Europe pads were structurally superior to the previous types of pads. None of these pads failed by rupturing or cracking as did the pre-Europe pads. However, the lightest test pad experienced excessive wrinkling. The woven roving reinforcement and the improved resin system were mainly responsible for the more desirable pads.

The results of the wheel load and element specimen tests showed a significant amount of scatter which can be attributed mainly to variations in thickness and glass content along the pads.

(2) Site Size and Shape Criteria

The previously developed theory for single uniform jets agrees fairly well with the model test data in-so-far as estimating landing pad size requirements is concerned. The predicted site sizes are consistently 5 to 7 percent smaller than those determined from model test data. The theory is to be modified to more closely predict downwash velocities along the ground for multiple source flow fields.

The concept of using fences along the pad edge to decelerate the downwash appears very promising, and pad diameter reductions of as much as 30 percent are expected based on model test data.

The analysis of pad lifting forces has shown that turbo-jet VTOL aircraft producing exhaust dynamic pressures in the range of 300 to 1,000 PSF produce aerodynamic forces over bumps on the pad great enough to lift or roll back the edge of the pad. Some means of edge restraint is required to prevent the edge from being lifted.

#### d. Remote Site Preparation

Two VTOL remote sites were prepared in England from which P.1127 aircraft flight operations were successfully conducted. While cracking of both sites occurred, a patching technique was successfully employed to repair the cracked areas. A total of 26 take-offs and landings were made from the 66-foot site. No edge lifting occurred. Taxiing of the aircraft over this pad did not harm it. No significant heat effects from the aircraft exhaust were noted.

Primary cause of the cracking of the English sites is believed to be the shrinkage of the polyester resin combined with a low percentage fiberglass reinforcement. Quite possibly the tenacious grass-root structure to which the pad adhered contributed to the build up of shrinkage stresses by restraining the pad. In the German site, the restraint was provided by the bonding of the pad to the concrete taxiway and runway adjacent to the site, the surface of the concrete being sheared in several places.

A turned-down edge around the periphery of the pad was completely effective in preventing downwash getting under the P.1127 sites. The VJ101C-X2 aircraft downwash caused severe lifting of the German pad due to an exposed edge which was not made in this manner.

The strength of the remote sites appeared to be marginal for the P.1127 and VJ101C-X2 aircraft wheel loads although one P.1127 site did withstand taxi tests successfully.

#### e. Logistics Analysis

A VTOL rapid site deployment concept evaluation model was developed for this study which reflects the interactions of major factors dictated by VTOL operation.

The average transportation cost of rapid site preparation equipment and material in supporting a 72-, 48-, or 24-VTOL pad preparation mission is about 74% of the AM-2 aluminum mat concept. In terms of capital investment per pad, or average VTOL pad preparation cost, the same comparison yields a corresponding value of 59% and 56% respectively. These values are based on a 70-foot VTOL pad, 14,700 pounds of polyester resin-fiberglass material per pad, and operation conditions as described in Section VI. Current studies indicate that the required resin material can be reduced by as much as 46% for the same size pad without degrading the pad's usefulness.

The cost sensitivity analysis indicates that the rapid site preparation mission cost of the above logistics support evaluation model is highly sensitive to the required amount of material, but relatively insensitive to the change of equipment weight or material spray rate. For example, a 50% reduction in material can provide a 48.5% reduction in VTOL site preparation cost, whereas a 50% reduction in equipment weight or a 100% increase in spray rate, yields a corresponding cost reduction of only 2.2%.

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## 2. RECOMMENDATIONS

### a. Material Formulation

Both filled and unfilled resin systems should be evaluated for improvement in one or more of the following properties:

- (1) processability
- (2) lower cost

Various catalysts and promoter systems should be investigated as to their storage, curing, and shipping characteristics.

An investigation should be made to improve reinforcement material with respect to strength, cost reduction, or processability.

### b. Application Equipment

The operational experience and concept study results from Phase II should be applied to a more extensive program of concept study and subsystem development during Phase II. Several system concepts should be subjected to preliminary design analysis, and estimates prepared of system weight, size, cost, and other characteristics.

Simultaneously with the foregoing, detailed design, analysis, and development testing should be conducted on critical subsystems common to the several concepts mentioned above. These include: improved resin spray nozzles for use singly or on spray bars, eliminating, if possible, the use of air as a catalyst injecting and resin dispersing medium; automatic injection and proportioning of catalyst and promoter during resin pumping to eliminate the operator control and monitoring function of the present system; improved (or different) system for dispensing continuous roving fiberglass, to reduce malfunctions and simplify reloading operations; improved design of pole guns, hoses, and supporting devices to reduce operator fatigue; multi-nozzle spray bars and booms for mechanized systems; improved monitoring and control systems for the foregoing.

### c. Site Design Requirements

#### (1) Site Thickness Criteria

Additional wheel load pad tests are needed before a functional site-thickness design criteria can be finalized. These tests must be performed on different types of soil with various CBR values. Also, it will be necessary to test a number of pads of constant thickness on each type of soil.

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Improvements in pad preparation techniques are necessary in order to control the glass content, the location and continuity of the glass fibers, and the overall pad thickness from point-to-point. This will give a more homogeneous pad, eliminate any unnecessary weak spots, and reduce the amount of scatter in the test results.

Cone penetrometer readings should be discontinued as a criteria for a soil's load-carrying capability which can be defined more accurately by CBR. However, cone index can still be used as a check for maintaining constant soil conditions when repreparing the soil between pad tests. Also, no attempt should be made to control or monitor minor variations of CBR in a specific soil.

It will be necessary to incorporate the effects of repeated loads (i.e. rolling wheel loads that occur during the pad demonstration tests) in establishing a site-thickness design criteria as well as defining allowable deflections for static loads.

## (2) Site Size and Shape Criteria

Reliable downwash data must be acquired for actual aircraft operations over the landing sites to prove the theoretical predictions and to correlate with model test data. Ground jet roll-up and recirculation should be investigated to define the environment in which the aircraft must operate.

The concept of downwash fences at the edge of the landing site should be investigated through further model testing and full-sized tests to fully establish the advantages and disadvantages of the fences.

### d. Remote Site Preparation

Additional capabilities for hoisting and handling materials or equipment in the field are desirable for a self-sufficient field operation.

While the "cookie-cutter" wheel made a suitable groove in some soils for the turned down edge of the pad, modification of the method is required to provide an improved edge under various soil conditions. This improvement should be coordinated with other edge treatment studies.

The preparation of remote sites of large size (3,500 square feet or more) requires application equipment with greater capacity and automated operation to decrease total fabrication time and to reduce personnel effort.

e. Logistics Analysis

Additional efforts should be directed toward the examinations of logistics support requirements, rapid site preparation mission cost evaluation and the rapid site preparation system cost parameter sensitivity.

The findings from current studies in rapid site preparation system performance requirements and cost sensitivity analysis should be used to establish guidelines for the Phase II rapid site preparation system performance effectiveness tradeoff analysis will be required as better understandings are gained in VTOL pad design, resin material selection, resin spray techniques, application of other potential rapid site preparation material, and VTOL site utilization. This tradeoff study can help in defining the characteristics of second generation rapid site preparation spray equipment.

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- 1 Rapid Site Preparation for Turbojet VTOL Aircraft, J. E. Butler and G. F. Thomas, Report No. APL-TDR-64-125, October 1964.
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- 5 Engineering and Design of Flexible Airfield Pavements, US Army Corps of Engineers Manual No. EM 1110-45-302, 15 May 1964.

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13. ABSTRACT Experimental application equipment for the preparation of remote landing and take-off sites for turbo-jet VTOL aircraft was designed, fabricated and demonstrated. Three full scale remote sites were prepared in England and the Federal Republic of Germany. Evaluation of these sites was accomplished with the P.1127 and the VJ101C-X2 aircraft respectively. These remote sites were prepared by spraying a modified chlorinated polyester resin and fiberglass roving over essentially unprepared ground. Modifications to the application equipment, further development of materials and fabrication techniques were made as a result of the experience gained in the preparation and evaluation of these remote sites.  Preliminary remote site design criteria were developed for determining site thickness, site size and shape. Experimental pads were prepared over various soil types and tested using typical wheels and tires to obtain data for determining site strength requirements. A methodology for determining site size and shape was further refined by conducting downwash flow field studies using models of the P.1127, VJ101, XC-142 and DO-31 aircraft. Dynamic pressure data obtained during remote site evaluation were correlated with model test data. Logistics support tasks for VTOL site preparation and site operation were examined.			

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It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).  
There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.
14. **KEY WORDS:** Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

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