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FINAL REPORT ON THE ENERGY RELATED INVENTION CALLED LINE FOCUSING ADJUSTABLE PARABOLIC SOLAR CONCENTRATOR

By
Richard E. Dame

September 30, 1983

Work Performed Under Contract No. FG01-81CS15072

Mega Engineering
Silver Spring, Maryland

TECHNICAL INFORMATION CENTER
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F I N A L   R E P O R T

LINE FOCUSING ADJUSTABLE PARABOLIC SOLAR CONCENTRATING COLLECTOR

1 Introduction and Background

This is a final report and analysis for an "Adjustable Focus Concentrating" (AFC) line focus collector, an energy-related invention. This device is a concentrating collector scheme which permits development of a very accurate line focus parabolic concentrating collector system by means of actively tuning a flat sheet of reflective material.

The shape created by flexing this thin sheet can approximate a parabolic collector system very well. Since this is possible, the device has the potential to reduce the fabrication and assembly costs for line focus concentrating solar collectors.

The purpose for the present project was to commercialize this concept. The project, therefore, was directed at evaluation of the design for potential commercialization and for fabrication. In this effort, several tasks were undertaken. These included:

- Prepare a Value Engineering Study to reduce overall fabrication costs,
- Develop a Marketing and Commercialization Plan,
- Evaluate the potential for reducing systems costs by improving overall system's design,
- Develop a prototype installation for test, evaluation, and demonstration purposes.

As a result of these tasks, the present system costs have been evaluated for installation of these collectors on a commercial basis. The project has developed commercial versions of the collectors (see attached drawings for these collectors as Figures 1 through 10). The market feasibility for this item has also been evaluated in view of the current 1983 energy costs.

2 Overview of Tasks Completed

This Report, along with its supporting Cost and Management Report, is being submitted as a Final Project Report. This work was carried out for the eventual commercialization of an Adjustable Focusing Concentrating (AFC) Collector System.

The purpose of this research grant was to develop and commercialize a relatively low cost mass producible line focusing concentrator and to surface any existing problem areas associated with this invention. Much of the technical work was directed toward the development of:

- Glass reflector design,
- High temperature evacuated receiver system,
- Support frame configuration design,
- Selection of a commercial tracking system,
- Commercial promotion of the collector.

The tasks performed in each of these areas are described in more detail below. This report has been divided into three areas:

- Technical Work Performed
- Management Plans and Commercialization Plans,
- Cost and Contractual Status.

2.1 Value Engineering and Cost Analysis

Costs for manufacturing line focusing solar collector troughs and their installation are currently difficult to justify by their resulting fuel savings. This has been increasingly true in recent years with the reduction of fuel costs after the peak prices in 1981. Most concentrating collector systems would cost around $50-$60/square foot of aperture area in the 1983 market. One major problem with these devices is their high cost for fabricating the collector line focus troughs themselves. The typical methods used for their fabrication are shown in the attached Table 1.

Not only are reductions in costs for fabricating this item now possible, but additional improvements in the optical performance over these previous concentrating trough systems are now possible using the AFC trough fabrication method. Based upon the present concept and related concentrator technology, a reduction in these collector costs is anticipated. Our current 1983 fabrication cost estimates (based upon a single unit with a nominal mark up) for the AFC system are:

TABLE 1

AFC System Installed Costs

Item	% Total	Cost - $/sf
Collector	43.0	15.10
Drive	18.0	6.40
Support	25.0	8.60
Control	9.0	3.10
Plumbing	5.0	1.38
Total	100.0	34.58

The present invention and current DOE energy related invention grant supported research work were directed toward providing additional reductions in these costs and, at the same time, to increase the system's reliability.

The ultimate intent of the grant was to foster commercialization of this AFC reflector which would permit it to compete with existing, more expensive fossil-fueled devices as well as with other more expensive concentrating collector fabrication methods.

As described in more detail below, typical applications for the AFC include food processing, industrial process heat applications, solar power production and, to a lesser degree, agricultural pumping of water.

2.2 Detailed Work Performed During This Project

During this the project, technical work was performed which would develop a collector reflector substrate and support frame (i.e., the metal and glass material which supports the collector reflector as shown in Figure-1 in Appendix A of this report). A material which has a better specular reflectance and weatherability than the previous 3M acrylic film reflectors used by MEGA (see Table 2) was desired. Work was also performed on integrating an improved receiver system, tracking system and support system. The emphasis in each of these areas has been to explore commercially available items which would closely match the required system's specifications.

TABLE 2 Potential Applications of Solar Thermal Energy Systems for Industrial Process Heat

Industry/process	Energy form*	Temperature, °F	Estimated time of technological readiness†	Shallow ponds or simple air heaters	Flat plates	Fixed compound surfaces	Single-tracking troughs	Central receivers
Aluminum								
Bayer process digestion	Steam	420	1985				X	
Automobile and truck manufacturing								
Heating solutions	Steam (water)	120–180	1980	X	X			
Heating makeup air in paint booths	Air	70–85	1980	X				
Drying and baking	Air	325–425	1985			X	X	
Concrete block and brick								
Curing product	Steam	165–350	1985			X	X	
Gypsum								
Calcining	Air	320	1985			X	X	
Curing plasterboard	Steam (air)	570	1990				X	X
Chemicals								
Borax, dissolving and thickening	Steam	180–210	1980		X	X		
Borax, drying	Air	140–170	1980	X	X			
Bromine, blowing brine/distillation	Steam	225	1985			X		
Chlorine, brine heating	Steam (water)	150–200	1980	X	X			
Chlorine, caustic evaporation	Steam	290–300	1985			X	X	
Phosphoric acid, drying	Air	250	1985			X		
Phosphoric acid, evaporation	Steam	320	1985				X	
Potassium chloride, leaching	Steam	200	1980		X	X		
Potassium chloride, drying	Air	250	1985			X	X	
Sodium metal, salt purification	Steam	275	1985			X	X	
Sodium metal, drying	Steam (air)	240	1985			X	X	
Food								
Washing	Water	120–160	1980	X	X			
Concentration	Steam (water)	100–200	1980	X	X	X		
Cooking	Steam	250–370	1985			X	X	
Drying	Steam (air)	250–450	1985			X	X	
Glass								
Washing and rinsing	Water	160–200	1980	X	X			
Laminating	Air	212–350	1985			X	X	
Drying glass fiber	Air	275–285	1985			X	X	
Decorating	Air	70–200	1980	X	X	X		
Lumber								
Kiln drying	Air	150–210	1980	X	X	X		
Glue preparation/plywood	Steam	210–350	1985			X	X	
Hot pressing/fiberboard	Steam	390	1985				X	
Log conditioning	Water	180	1980		X			
Mining (Frasch Sulfur)								
Extraction	Pressurized Water	320–330	1985			X	X	
Paper and pulp								
Kraft pulping	Steam	360–370	1985				X	
Kraft liquor evaporation	Steam	280–290	1985			X	X	
Kraft bleaching	Steam	280–290	1985			X	X	
Papermaking (drying)	Steam	350	1985				X	
Plastics								
Initiation	Steam	250–295	1985			X	X	
Steam distillation	Steam	295	1985			X	X	
Flash separation	Steam	420	1985				X	
Extrusion	Steam	295	1985			X	X	
Drying	Steam	370	1985				X	
Blending	Steam	250	1985			X	X	
Synthetic rubber								
Initiation	Steam (water)	250	1985			X		
Monomer recovery	Steam	250	1985			X		
Drying	Steam (air)	250	1985			X		
Steel								
Pickling	Steam	150–220	1980	X	X	X		
Cleaning	Steam	180–200	1980		X	X		
Textiles								
Washing	Water	160–180	1980	X	X			
Preparation	Steam	120–235	1980	X	X	X		
Mercerizing	Steam	70–210	1980	X	X	X		
Drying	Steam	140–275	1980	X	X	X		
Finishing	Steam	140–300	1980		X	X	X	

*Preferred form (secondary form).

†Demonstrated thermal efficiency and reliability for 10 years.

SOURCE: Battelle Columbus Laboratories et al., "Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat," pp. 22–24, Report No. TID-27348/1, U.S. Energy Research and Development Administration, January 1977.

The previous MEGA AFC designs and field tested prototypes used flexible aluminum substrates with 3M FEK acrylic material reflecting surfaces. The weathering characteristics of this FEK material were not adequate for a planned 20-year life. In addition, the labor required to coat the aluminum sheets was also extensive, and the costs required to support the replacement of these reflectors periodically would be too costly. It was then planned to evaluate the potential of bending thin glass sheet material for the AFC project.

In a related project, under the SERI "Accelerated Commercialization Program for Materials and Components - Solar Sheet Glass Project," the problems of bending and handling such tempered thin glass sheets were evaluated. This work was carried out by the Corning Glass Company using Corning 7809 Solar Fusion glass.

Unfortunately, this glass will not be commercially available in the U.S. on a production basis in the thickness (.25mm). However, a similar glass reflector is currently available from Glaverbel of Belgium. The feasibility of using this source was good, and MEGA has purchased sufficient material stock to fabricate 4 collectors. The support frames have been altered to accept these larger dimensioned sheets of glass.

The present AFC design will use, as a baseline, a thin sheet of second surface silvered glass bonded to a thin gauge steel substrate. The parabolic shape can be developed by using edge couples and controlled positions for the edge generator support points (see Figures 1,2 and 3 of Appendix A to this report). This requires bending of the flat thin sheets of bonded glass and steel materials. This sheet can be flexed sufficiently to form a parabolic shape within the constraints of limiting the mirror material stresses and within the available geometric limits of the glass sizes.

In a parallel effort, the potential for using ALZAK reflector sheet material has also been pursued. These conventional lighting reflectors do not have the high specular reflectance of either the acrylic or glass plate materials; yet, they have the weathering characteristics necessary and an acceptable reflectance (see Table 2). Costs for this material are higher than for the glass reflector materials. This "ALZAK" material would be an acceptable choice if its costs had been sufficiently low. Sample sets of these reflectors have also been procured from ALCOA for one reflector trough.

2.3 Support and Drive System Development

The previous AFC test units were mounted to track the sun about either a single axis or about two axes. In these models, the focal line of the concentrator coincided with the axis of the rotation of the parabolic trough. All receiver tube plumbing had to pass through a set of support bearings. Complications of this "through-the-bearing" mounting of the receiver tube dictated the size of the support, and made alignment of the receiver and reflector difficult.

The present concept has an independent support for the trough with the receiver mounted on separate brackets attached to the frame. This design is shown in Figures 1 through 12 of Appendix A to this report.

Rotation of the reflector was previously accomplished with a reversible motor controlled by a solid state clock drive controller which received update inputs from a sun sensor mounted on the reflectors. Mechanical drive of all collectors was through a chain drive sprocket attached to the support bearing shaft at each collector end support.

The present design has eliminated the combined "gang drive" system which used a long chain to drive the collectors. The collectors are driven through a torque shaft system which has been sized to minimize angular phase lagging during driving. The revised support system minimizes the complexity of this drive system. This new design also permits "up-side down" stowage to protect the collector during snow dust or hail storms.

The tracking system consists of a Z8761 microprocessor based controller system. The solid state device is a "basic" language programmable controller which has the capability of receiving sensor data through its analog to digital converter and sending output data to motor drive relay based on the program routine. The system offers combined control and data acquisition with remote access through an RS232 port by means of an "auto-answer modem".

2.4 Value Engineering of Supports

During the project, designs for this revised support design were prepared and sent to subcontractors for competitive bids. Based upon these bids and additional cost estimates, a Value Engineering analysis was prepared to minimize the cost of that support while maintaining its functional and performance specifications. As seen in the Cost Table-1 of Page 3 of this report, the collector support amounts to 25% of the total system cost. There was then a large incentive to reduce this component cost.

Work was also carried out on re-designing the support system for a commercially available receiver tube system. The commercially available evacuated tube receivers which were evaluated included the Owens Illinois Sunpak type tube, Philco Italiana, Thermomax evacuated heat pipe systems and the GE Dewar type receiver tube systems.

Our present design includes provisions for the Owens Illinois Sunpak type receiver as one which is capable of withstanding temperatures of 600-700 degrees F. The prototype set of four receiver tube sections have been procured for integration into the present frame structures.

In previous MEGA units, the receiver tube was a selective coated steel tube housed within a Pyrex glass shield. This receiver tube was .75" in diameter. The Pyrex shield was 1.25" inside diameter and 8´ long. Our present alternative design also uses a Corning glass tube and internal selective coated glass receiver tube. The tube is 2"O.D. Schedule 40 pipe. The internal pipe is a 1-1/4" O.D. steel schedule 40 pipe.

3 Prototype Installation

To prepare the present design for commercial production, a prototype systems design was made for a ski lodge located in Copper Mountain, Colorado. This site was selected primarily because the lodge operators were willing to cooperate in its installation and to assist in the payment for the system costs. The system was to be mounted on the roof of the restaurant and lodge building to augment the existing oil fired boiler systems at that site.

The system was designed for 15 collectors, and the mechanical interface with the facility was also designed. The entire project was to be financed by Helioscience of New York. The project was cancelled by Helioscience in June of 1983 in favor of a less complex flat plate collector system. As part of the prototype systems design, a mounting, tracking and drive system was developed for that site.

As part of that particular design a roof mounting system which would be light weight and functional was evaluated.

A series of alternate support and drive system configurations has been explored in terms of a structural analysis of gravity loads, wind loads, thermal loads, and stability loads. These loads were applied to analytical models (NASTRAN finite element models) to evaluate stresses and deformations.

Each support arrangement was evaluated, not only to verify its structural integrity, but also to determine distortion effects on the optical performance under wind loads and support settlements expecte

4 Commercialization Plan

There are a number of potentially feasible industrial applications for the MEGA AFC concentrating solar collector reflectors. Table 3 shows the general range of temperatures and corresponding industries which are involved with energy use in those temperature ranges. Table 3 indicates the amount of energy consumed in each range. Figure 13 also indicates the range of temperatures applicable for different collector types as a function of their instantaneous efficiencies. From that Figure, it can be seen that the AFC concentrator would be competitive in temperature applications above 300 degrees F up to the practical limit of 450 degrees F which is the point at which heat transport fluids degrade and surface coatings degrade. According to Table 3, the most attractive industries in this area are in the food processing industry. This potential application has been identified as a suitable target for concentrator applications. Industrial process steam is also a general target to which commercial applications should be directed.

In both of these areas, we have made contact with and have proposed joint efforts with several organizations.

For example, we have proposed a joint venture with SECO Industries (kitchen equipment manufacturers). This project proposed to develop a high temperature kitchen thermal power equipment system which is heated by solar concentrators. This would include heat for steam tables, deep fryers, and ovens for food processing operations.

In addition, the following industrial applications may be potential targets for solar concentrator uses which have been briefly explored and which can be investigated at a later date:

- Developing steam for high temperature thermal process heat such as the MISER program. (Initial inquiries were made into this program for this purpose).

- Solar augmented second stage oil recovery. (Published reports indicated that the systems costs would have a hard time to compete with recovered oil itself as a source of power for steam generators).

- Photovoltaic applications (initial contacts have been made with photovoltaic corporations to explore the use of the AFC system for solar intensifiers for photovoltaic systems).

Summary of Process Heat Requirements for Selected Industries in the Unhed States*

SIC Code	Description	Hot water <212°F	Steam 212–350°F	Steam >350°F	Direct heat/hot air <212°F	Direct heat/hot air 212–350°F	Direct heat/hot air >350°F	Rounded totals
1211	Bituminous coal and lignite						11	11
1477	Sulfur mining		44					44
20	Food and kindred products	60	275	100	10	95	15	555
22	Textile mill products	19	191	4		69	13	296
24	Lumber and wood products	5	21	4	106	4	70	210
26	Paper and allied products		465				94	559
28	Chemicals		1400			450	250	2100
2911	Petroleum refining		120	380			2600	3100
32	Stone, clay, and glass	8	20	37		24	1081	1170
3312	Blast furnaces and steel mills		65				1712	1777
3331	Primary copper	14.2			2.4		55.4	72
3334	Primary aluminum			38.4			63.1	102
3711 3712 3713	Automobile and truck manufacturing	13	1.4		21.3	10	0.9	47
	Rounded totals	120	2600	563	140	652	5965	10,040
	Percent of total	1.2	25.9	5.6	1.4	6.5	59.4	

*Figures in 10^{12} Btu/year.

SOURCE: Battelle Columbus Laboratories et al., "Survey of the Application of Solar Thermal Energy Systems to Industrial Process Heat," p. 15, Report No. TID-27348/1, U.S. Energy Research and Development Administration, January 1977.

TABLE 3

- Solar furnace applications (A Heliostat system was proposed for the NASA Langley Virginia facilities which would use the AFC system to power a CO2 Laser system. This is still in the evaluation phases for funding by NASA.)

- Rankine cycle engine applications. (Under a separate research activity an engine system was built and tested. Efforts are now under way to obtain R&D limited partnership money to develop a new project for R&D which would include the line focus AFC system).

- Absorption refrigeration and air conditioning. (A proposal was prepared and submitted to AP parts of Toledo, Ohio. The interest was very good initially. However, with the reduction in oil prices this year, the project was put aside).

5 Management Report

The Principal Investigator for this project was Dr. Richard E. Dame. Dr. Dame is the inventor of this device and is a Registered Professional Engineer with over 23 years of professional engineering experience in Structural Engineering, Mechanical Engineering, and HVAC design using solar heating. Dr. Dame is an Adjunct Professor at the Catholic University of America and also has lectured in mechanical engineering, solar engineering (both passive and active), economics of energy usage and energy management at the Catholic University of America, Virginia Polytechnic Institute and State University.

Dr. Dame has also acted as the Project Manager for this grant. As the Project Manager, he has been responsible for assigning research tasks to senior mechanical engineers on the staff and has directed the research efforts for the reflector materials, receiver tube study, and support design efforts.

5.1 Engineering Staff Support

Dr. Dame was assisted on the project by a technical staff of engineers and mechanical designers from MEGA Engineering, all of whom are experienced in solar related mechanical design and analysis. The lead mechanical engineer was Mr. Harry A. Warren, a Princeton University and Stanford University graduate in Mechanical Engineering. Mr. Warren s experience includes design of active solar heating projects for commercial applications.

The structural/mechanical lead engineer was Mary Jean Studer. Her expertise in structural analysis and design includes design for the original collector support frames and extensive work with the NASA/GSFC on mechanical systems. Her efforts during the second quarter were aimed at developing the support frame structure.

The research and development related to the tracking system controller was carried out by Raymond Stattel. Mr. Stattel was a senior electronics engineer for NASA/GSFC and has had considerable experience in systems control device development for various agencies of the Federal Government. Maureen J. Reed assisted in the evaluation of the optical analysis, receiver distortion analysis and systems analysis. Systems overall thermal performance efficiency analysis was carried out by T. Chan using computer simulation techniques to trace the solar energy through the system optical and mechanical components.

Mega Engineering support staff of designers and engineers assisted in the structural analysis, thermal and optical analysis, and design activities. This staff also assisted in the preparation of concepts and proposals for the marketing of this device.

5.2 Administrative Staff Support

The administrative support for the project during the second quarter was provided by MEGA Engineering, which has an approved accounting system and property control accounting system. MEGA's administrative staff has had over 15 years of experience in contract administration with various Government agencies.

6 Costs to Date

The attached budget form represents the total project costs expended to date for this grant. The costs include monies expended for direct labor, materials and overhead for the project. No profit or interest has been charged for this project.

REFERENCES

(1) Dame, R.E., Elastic Bent Plate Concentrators, Proceedings of the 1980 Annual Meeting of the ASISEC, University of Delaware, May 31, 1980.

(2) Tu, King-Mon, Final Technical Review of the Adjustable Solar Concentrator, U. S. Department of Commerce, National Bureau of Standards, Recommendation No. 180, OERI No. 002116, April 14, 1981.

(3) U.S. Department of Energy Letter to R.E. Dame, ISD 180, from T. Coultas, Requesting a Work Statement, Washington, DC, April 29, 1981.

(4) Elzinga, E., et al, Solar Thermal Enhanced Oil Recovery (STEOR), Final Report under Contract No. DE-AC03-79CS30307, U.S. Department of Energy, Nov. 1980.

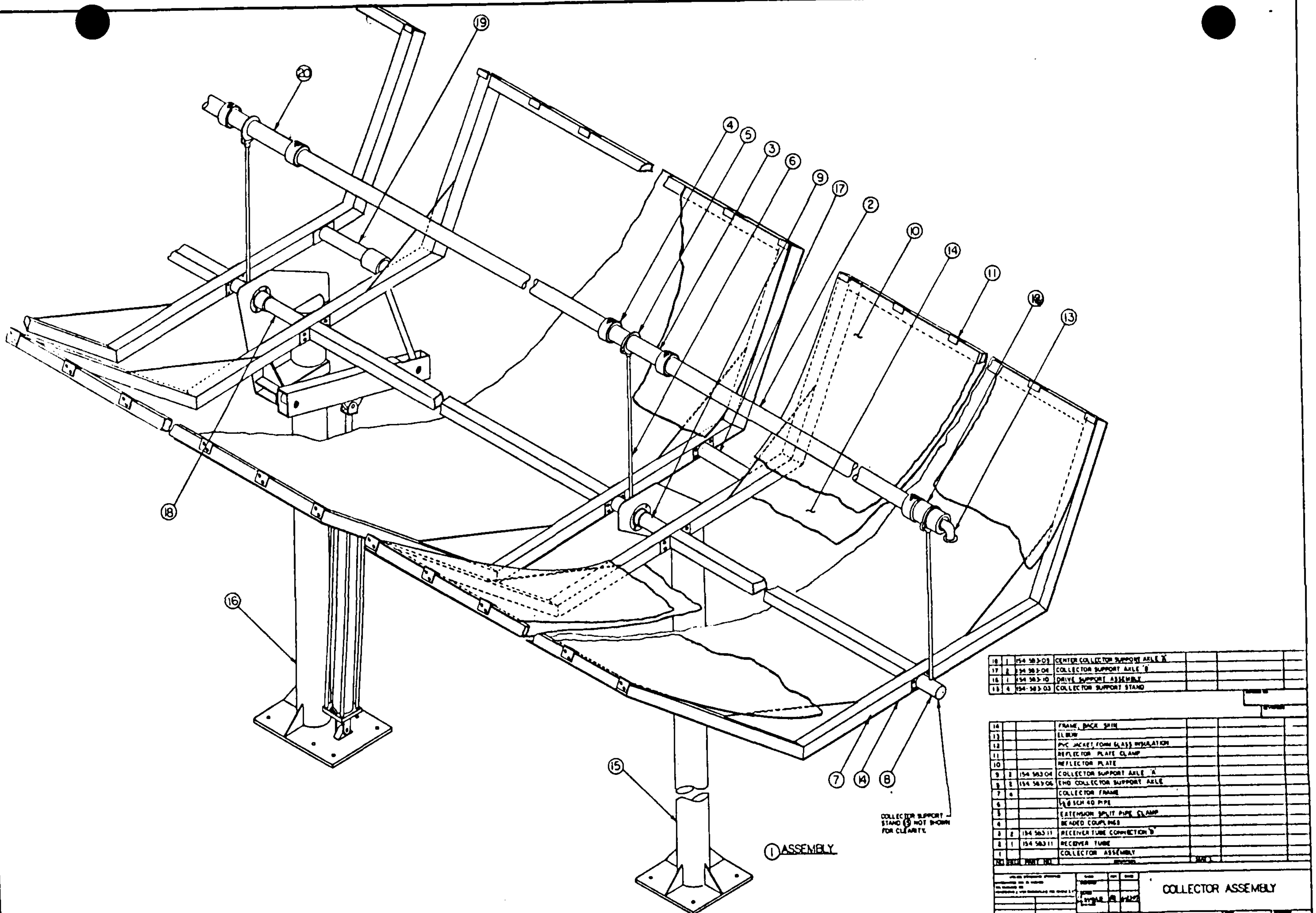
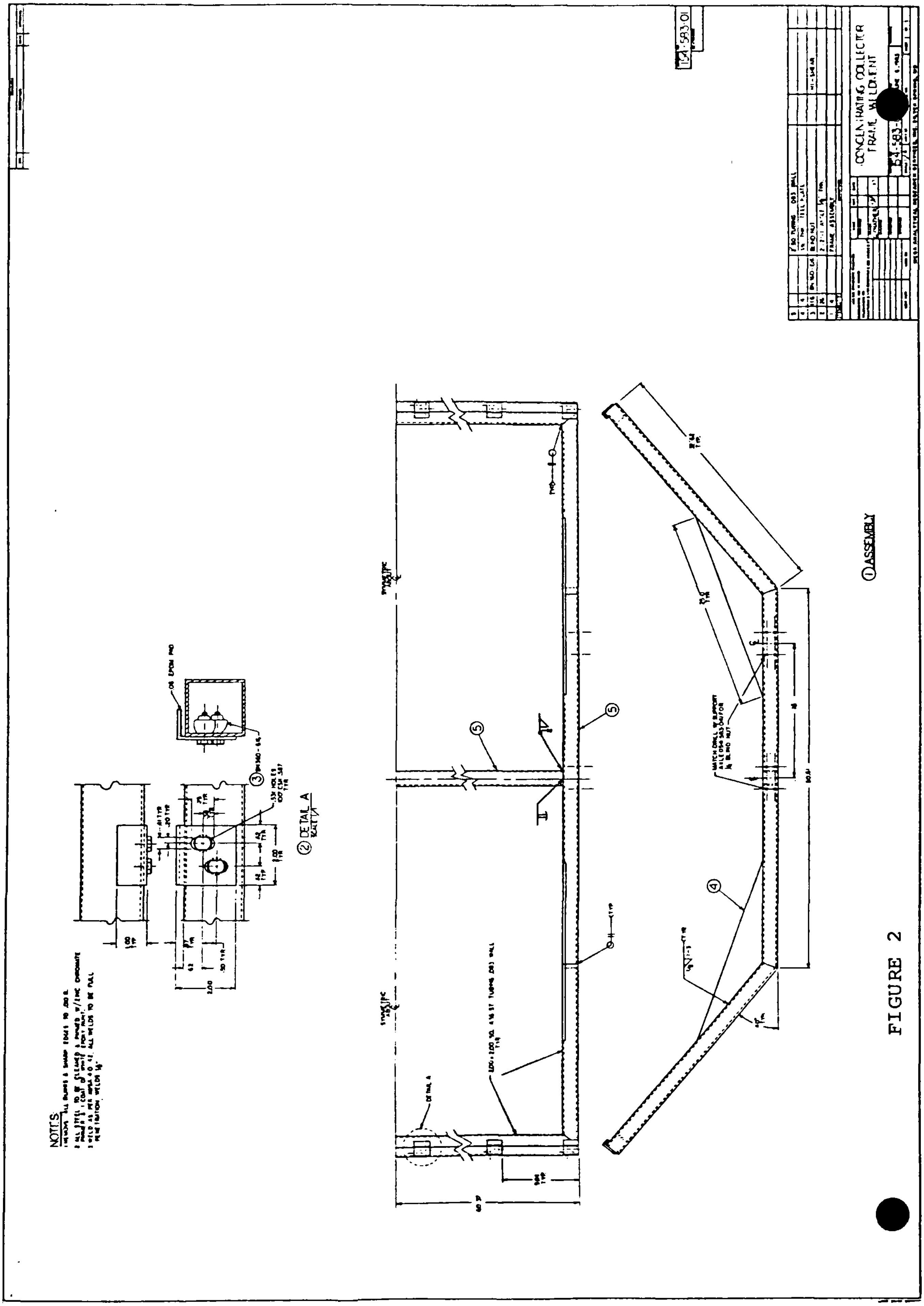
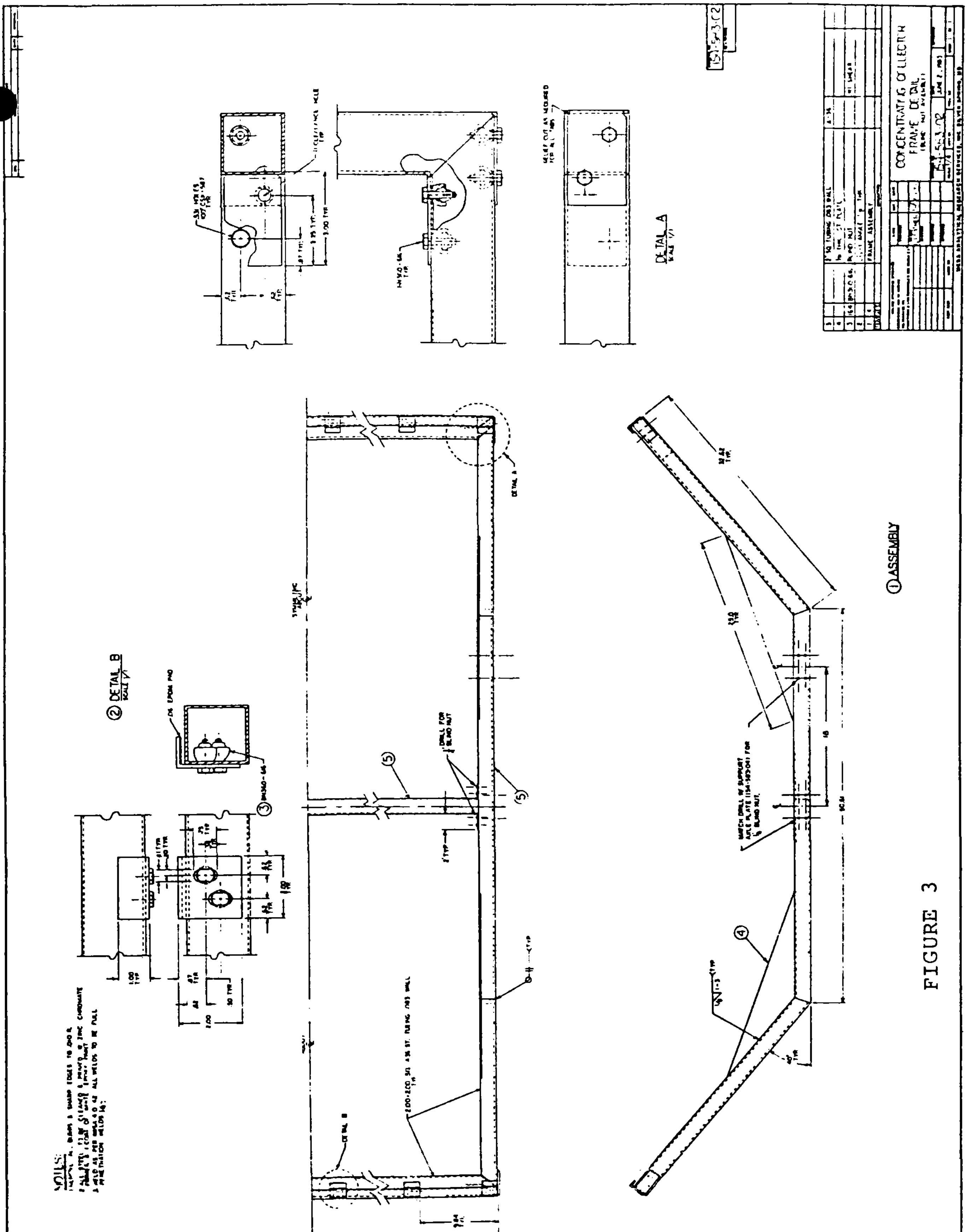

COLLECTOR SUPPORT STAND (15) NOT SHOWN FOR CLARITY.
(1) ASSEMBLY
18 1 154-583-05 CENTER COLLECTOR SUPPORT AXLE "X"
17 2 154-583-04 COLLECTOR SUPPORT AXLE "B"
16 1 154-583-10 DRIVE SUPPORT ASSEMBLY
15 4 154-583-03 COLLECTOR SUPPORT STAND
14 FRAME, BACK SKIN
13 ELBOW
12 PVC JACKET, FOAM GLASS INSULATION
11 REFLECTOR PLATE CLAMP
10 REFLECTOR PLATE
9 2 154-583-04 COLLECTOR SUPPORT AXLE "A"
8 2 154-583-06 END COLLECTOR SUPPORT AXLE
7 6 COLLECTOR FRAME
6 SCH 40 PIPE
5 EXTENSION SPLIT PIPE CLAMP
4 BEADED COUPLINGS
3 2 154-583-11 RECEIVER TUBE CONNECTION "B"
2 1 154-583-11 RECEIVER TUBE
1 COLLECTOR ASSEMBLY
NO. REQ. PART NO.
20 1 154-583-11 RECEIVER TUBE CONNECTION "X"
19 1 154-583-05 CENTER COLLECTOR SUPPORT AXLE "Y"
COLLECTOR ASSEMBLY
154-583-12

FIGURE 1



NOTES
① ASSEMBLY
② DETAIL A
CONCENTRATING COLLECTOR
FRAME WELDMENT

FIGURE 2



DETAIL A
② DETAIL B
① ASSEMBLY
NOTES:
CONCENTRATING COLLECTOR
FRAME DETAIL

FIGURE 3

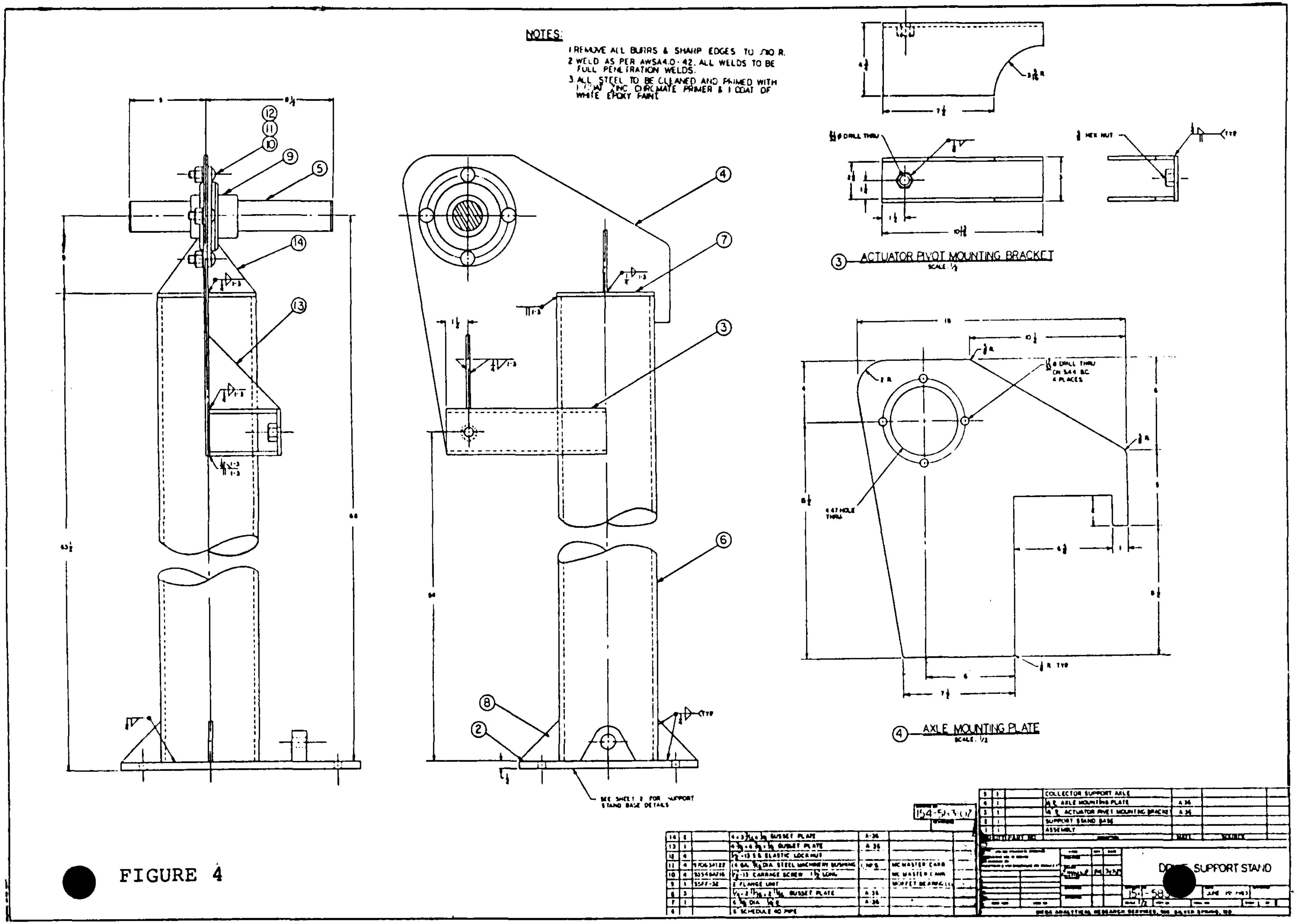
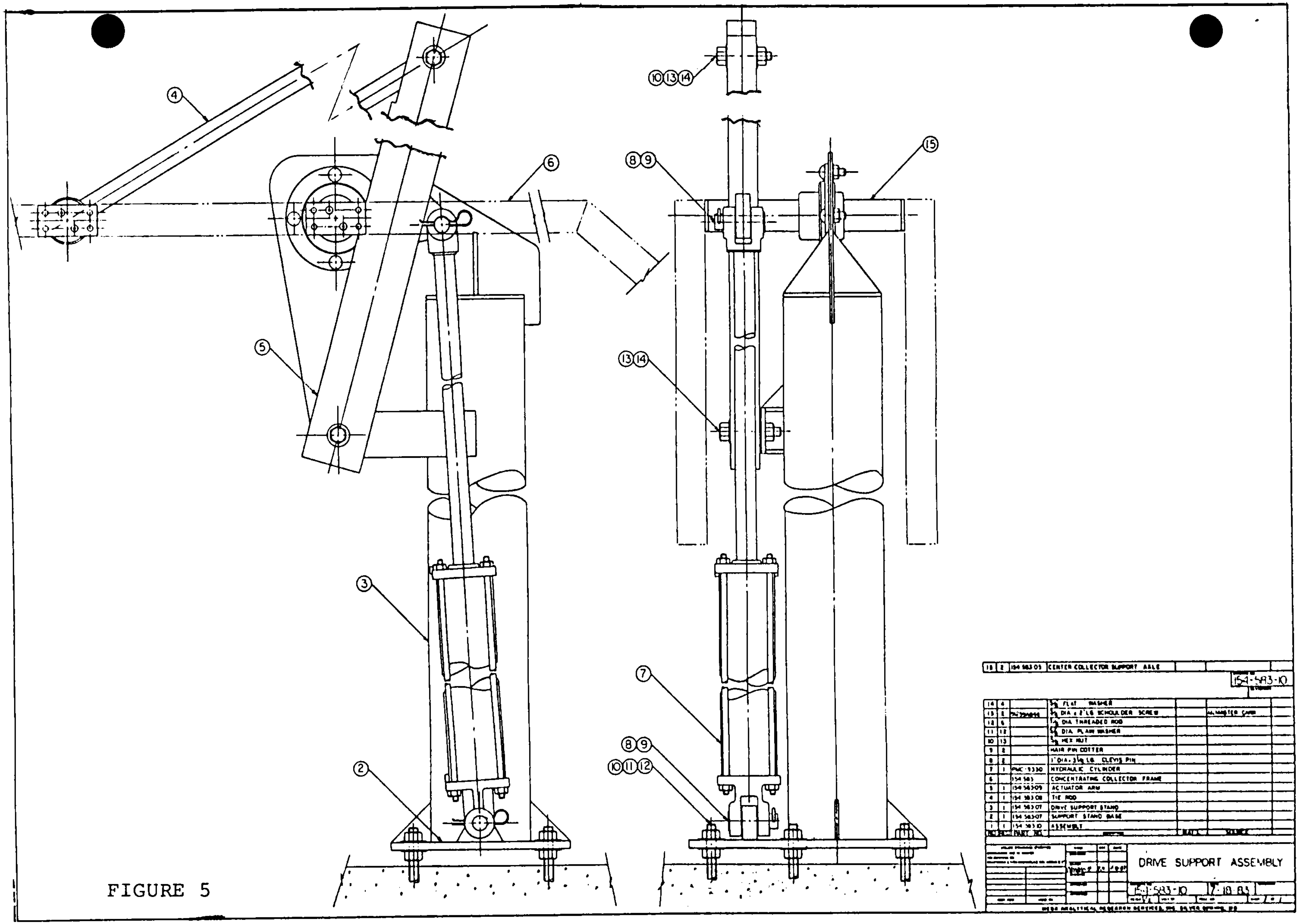

NOTES:
1 REMOVE ALL BURRS & SHARP EDGES TO .010 R.
2 WELD AS PER AWS A4.0-42. ALL WELDS TO BE FULL PENETRATION WELDS.
3 ALL STEEL TO BE CLEANED AND PRIMED WITH 1 COAT ZINC CHROMATE PRIMER & 1 COAT OF WHITE EPOXY PAINT.
③ ACTUATOR PIVOT MOUNTING BRACKET
SCALE ½
④ AXLE MOUNTING PLATE
SCALE ½
SEE SHEET 2 FOR SUPPORT STAND BASE DETAILS
SUPPORT STAND
154-58307

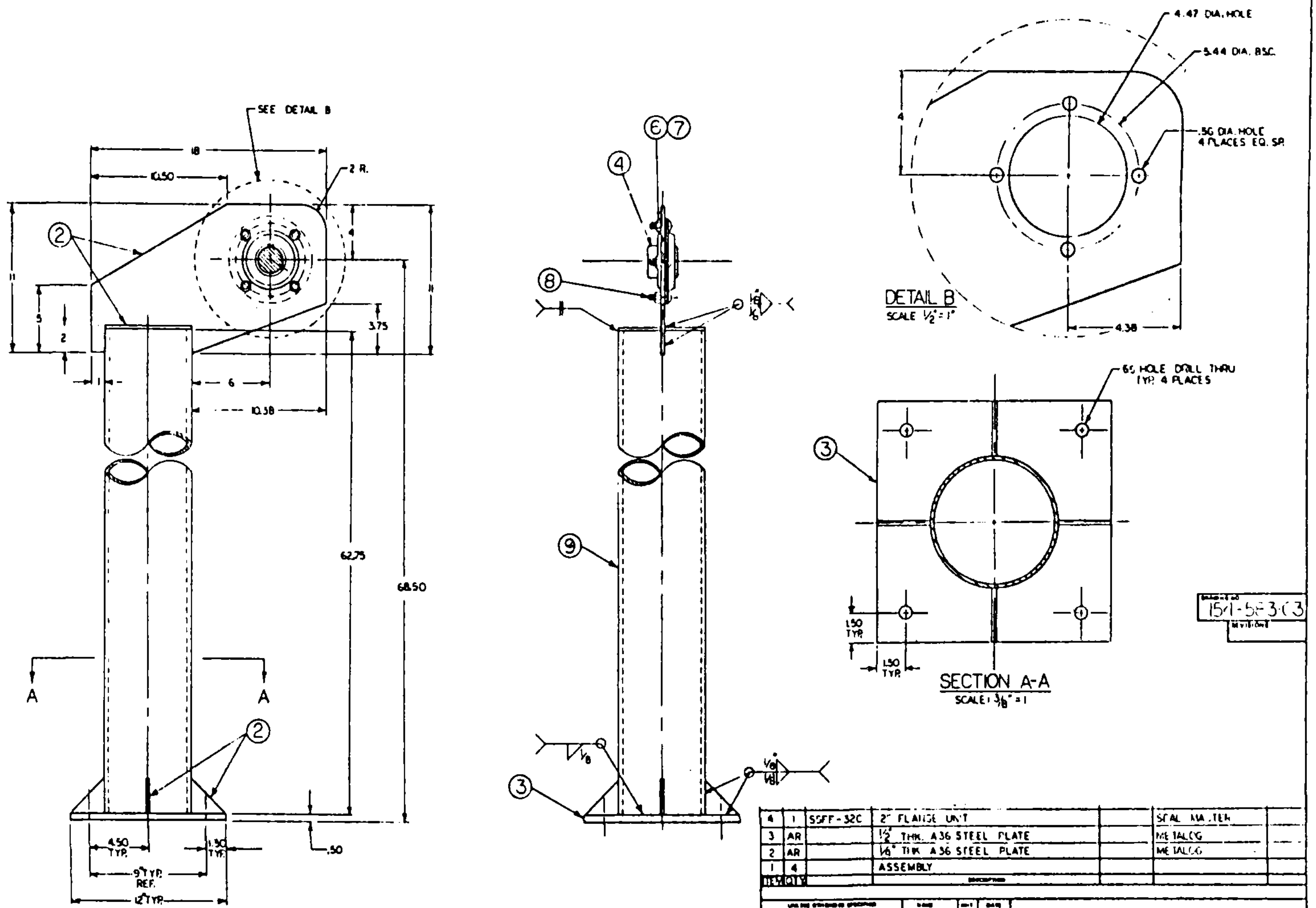
FIGURE 4



CENTER COLLECTOR SUPPORT AXLE
154-583-10
FLAT WASHER
DIA THREADED ROD
DIA PLAIN WASHER
HEX NUT
HAIR PIN COTTER
CLEVIS PIN
PMC-5330
HYDRAULIC CYLINDER
154 583
CONCENTRATING COLLECTOR FRAME
ACTUATOR ARM
TIE ROD
DRIVE SUPPORT STAND
SUPPORT STAND BASE
ASSEMBLY
DRIVE SUPPORT ASSEMBLY
154-583-10
7-18-85

FIGURE 5

NOTES:
1. REMOVE ALL BURRS & SHARP EDGES TO .010 R.
2. ALL STEEL TO BE CLEANED AND PRIMED WITH 1 COAT ZINC CHROMATE PRIMER & 1 COAT WHITE EPOXY PAINT.
3. WELD AS PER AWSA 4.0-42. ALL WELDS TO BE FULL PENETRATION.



9	1		6" DIA. SCH. 40 PIPE 62.75" LONG		KILBY-ROBERTS
8	4	93516A716	1/2"-13 CARRAGE SCREW 1 1/2 LG.		McMASTER CARR
7	4	97063A122	14 GAUGE 9/16 ϕ STEEL MACHINERY BUSHING		McMASTER CARR
6	4		1/2"-13 S.S. ELASTIC LOCKNUT		
4	1	SSFF-32C	2" FLANGE UNIT		SEAL MASTER
3	AR		1/2" THK. A36 STEEL PLATE		METALCO
2	AR		1/8" THK. A36 STEEL PLATE		METALCO
1	4		ASSEMBLY		
ITEM	QTY				

COLLECTOR SUPPORT STAND

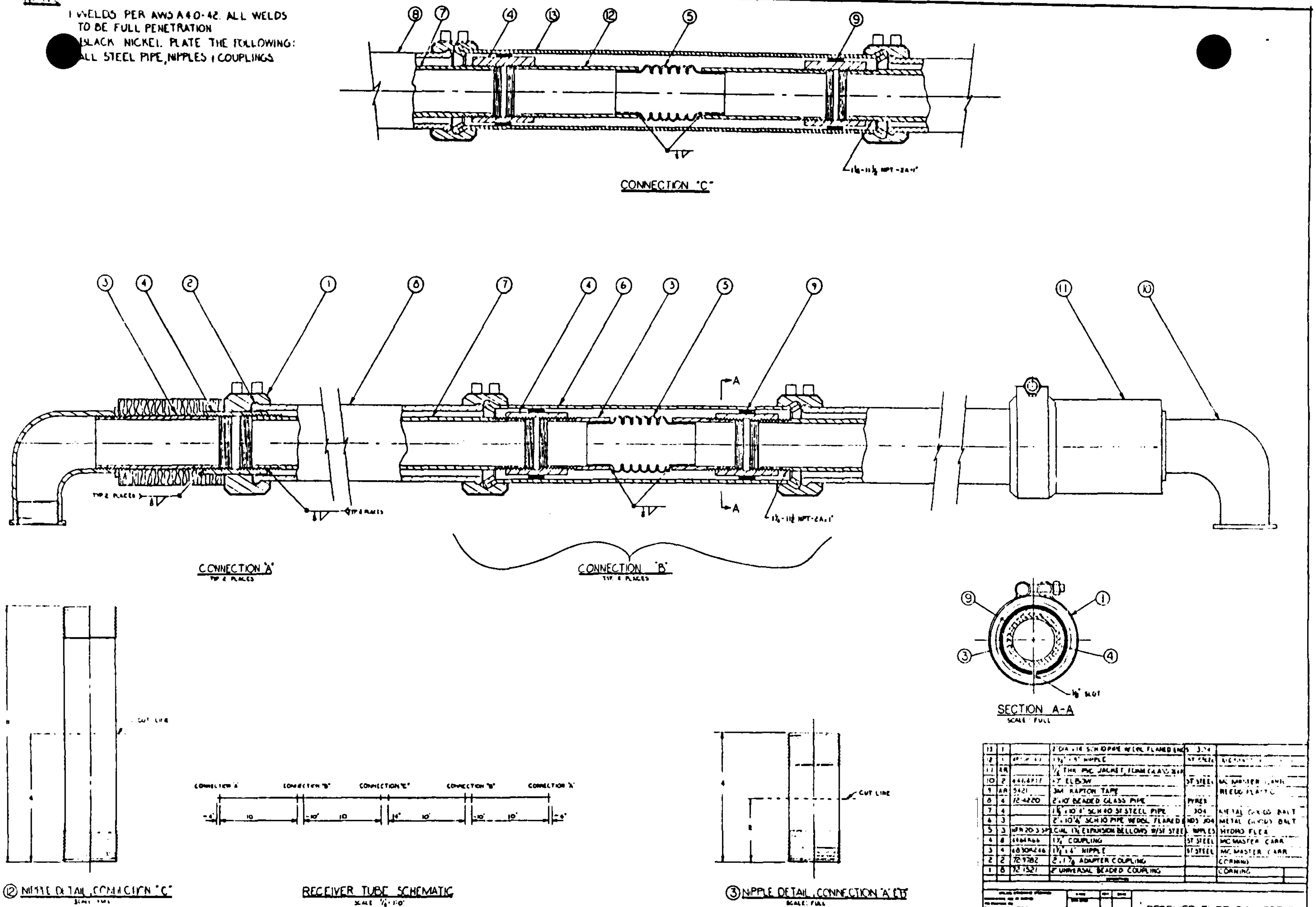
154-583-03 | JUNE 16, 1983 | SCALE 1/4 | SHEET 1 OF 1

MEGA ANALYTICAL RESEARCH SERVICES, INC. SILVER SPRING, MD.

FIGURE 6

NOTES

1. WELDS PER AWS A4.0-42. ALL WELDS TO BE FULL PENETRATION
2. BLACK NICKEL PLATE THE FOLLOWING: ALL STEEL PIPE, NIPPLES & COUPLINGS



13	1		2" DIA x 18 SCH 10 PIPE W/CPL FLARED ENDS	304	
12	1	[illegible]	1½" x 9" NIPPLE	ST STEEL	[illegible]
11	AR		½" THK PVC JACKET, FOAM GLASS INS		
10	2	4464K17	45° ELBOW	ST STEEL	MC MASTER CARR
9	AR	5421	3M KAPTON TAPE		REED PLASTIC
8	4	72-4220	2" x 10' BEADED GLASS PIPE	PYREX	
7	4		1½" x 10' 4" SCH 40 ST STEEL PIPE	304	METAL GOODS BALT
6	3		2" x 10' 6" SCH 10 PIPE W/DBL FLARED ENDS	304	METAL GOODS BALT
5	3	HPA 20-3 SP	SPECIAL 1½ EXPANSION BELLOWS W/ST STEEL NIPPLES		HYDRO FLEX
4	8	4464K66	1½" COUPLING	ST STEEL	MC MASTER CARR
3	4	4830K246	1½" x 6" NIPPLE	ST STEEL	MC MASTER CARR
2	2	72-9782	2 x 1½ ADAPTER COUPLING		CORNING
1	6	72-1521	2" UNIVERSAL BEADED COUPLING		CORNING

FIGURE 7

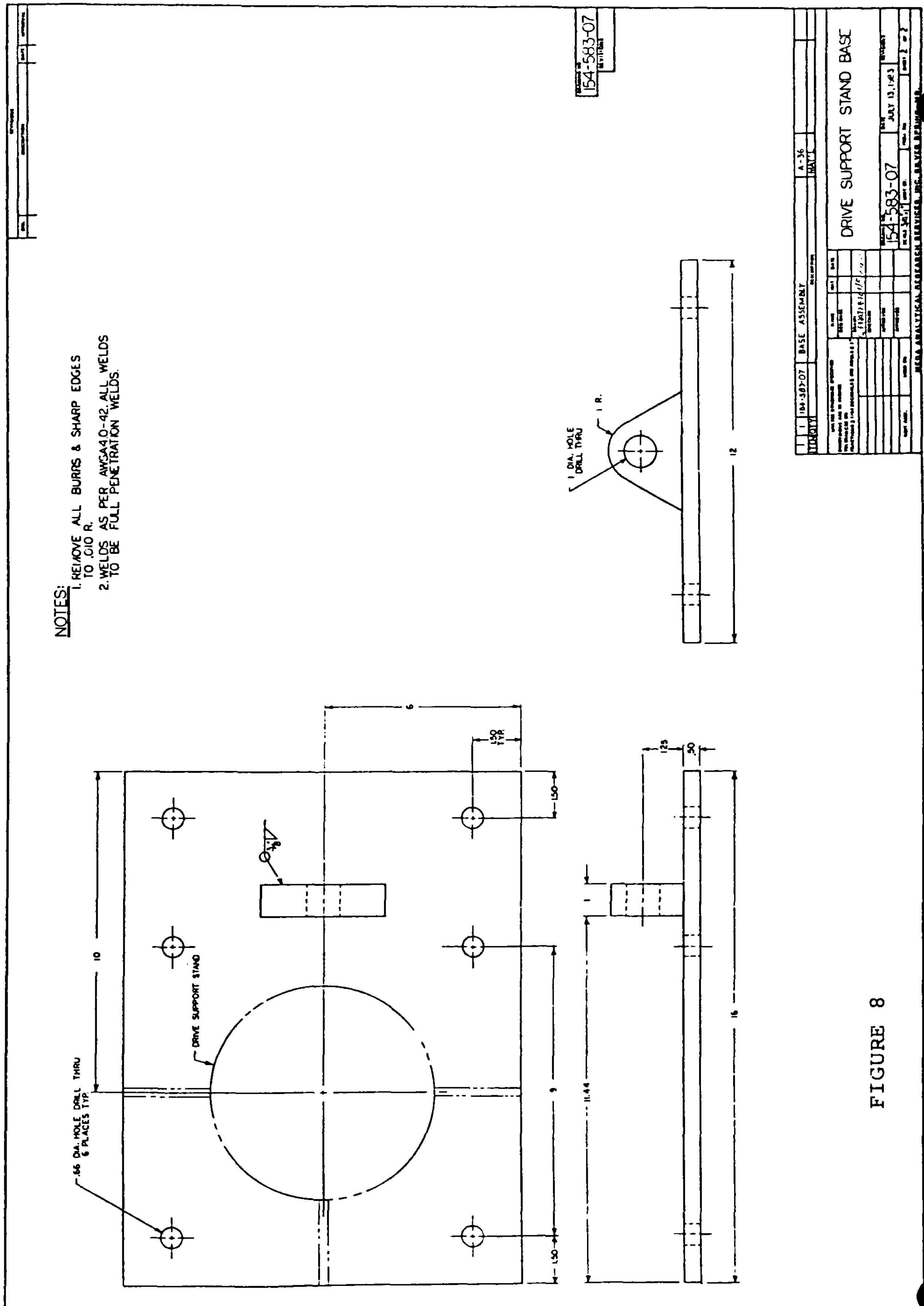
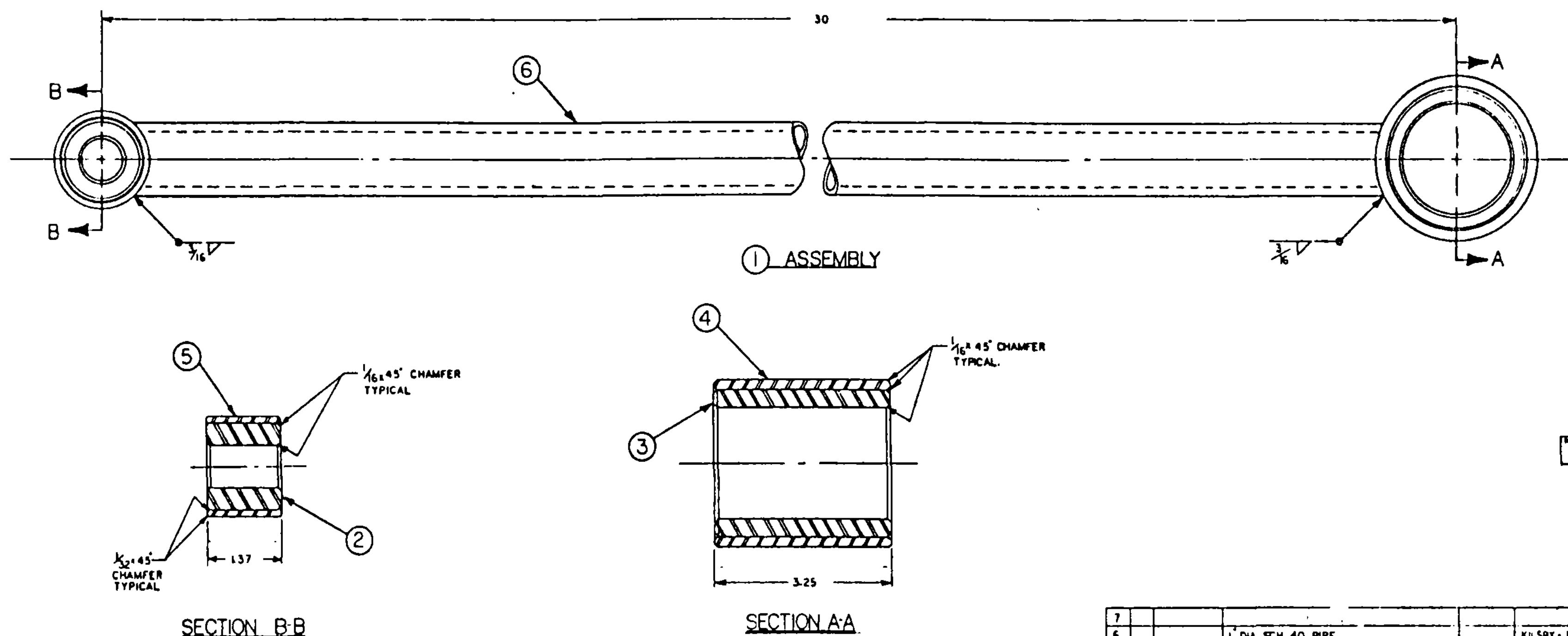


FIGURE 8

☆U.S. GOVERNMENT PRINTING OFFICE: 1983-746-081/2202

NOTES:

1. REMOVE ALL BURRS & SHARP EDGES TO .010 R.
2. WELD AS PER AWSA4.0-42. ALL WELDS TO BE FULL PENETRATION WELDS.
3. ALL STEEL TO BE CLEANED AND PRIMED WITH 1 COAT ZINC CHROMATE PRIMER & 1 COAT OF WHITE EPOXY PAINT.
4. PROTECT BUSHING WHILE PAINTING.



NO	REQ	PART NO	DESCRIPTION	MAT'L	SOURCE	
7						
6			1" DIA. SCH 40, PIPE		KILSBY - ROBERTS	
5			1 15/16" DIA x 1/8 THK. STEEL TUBING		KILSBY - ROBERTS	
4			3" DIA x 3/16 THK. STEEL TUBING		KILSBY - ROBERTS	
3	1	SSC-2600	2" SUPER OILITE BUSHING		OILITE	
2	1	SSC-1500	3/4" SUPER OILITE BUSHING		OILITE	
1	1		ASSEMBLY			

TIE ROD

DRAWING NO. 154-583-08 DATE 7-19-83

SCALE FULL SHEET 1 OF 1

MEGA ANALYTICAL RESEARCH SERVICES, INC. SILVER SPRING, MD.

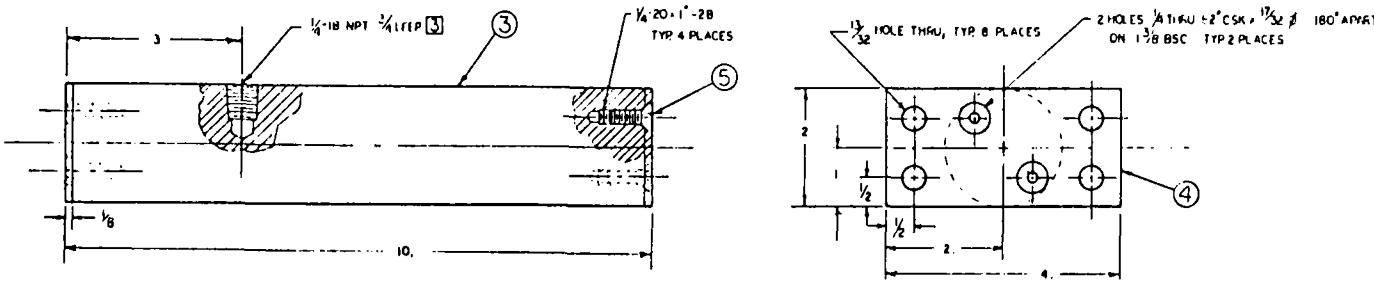
FIGURE 9

NOTES:

1 REMOVE ALL BURRS & SHARP EDGES TO .010 R

2 FINISH WITH (1) COAT ZINC CHROMATE AND (1) COAT WHITE EPOXY PAINT

[3] 1/4-18 NPT TAPPED HOLE ON 2 OF THE 4 AXLES.



①② ASSEMBLY

154-583-04

5	AR		1/4-20 × 3/4 FLAT HD HEX SOCKET CAP SCREW	CRES		
4	AR		1/8 STEEL PLATE	A-36		
3	AR		2" ⌀ STEEL ROUND BAR	A-36	KALSBY-ROBERTS	
2	2		ASSEMBLY W/O NPT THREADED HOLE			
1	2		ASSEMBLY W/NPT THREADED HOLE			

COLLECTOR SUPPORT AXLE

154-583-04

15-83

FULL

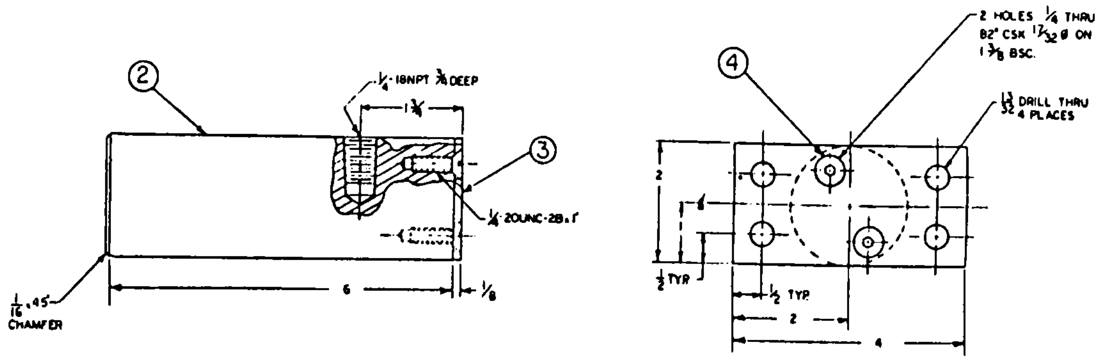
SHEET 1 OF 1

MERA ANALYTICAL RESEARCH SERVICES, INC. SILVER SPR...

FIGURE 10

NOTES:

1. REMOVE ALL BURRS & SHARP EDGES TO .010 R.
2. FINISH WITH (1) COAT ZINC CHROMATE PRIMER, AND (1) COAT WHITE EPOXY PAINT



154-583-06

4	4		1/4-20UNC x 3/4 FLAT HD HEX SOC CAP SCREW	CRES	
3	2		2 x 4 x 1/8 STEEL PLATE	A 36	
2	AR		2 Ø STEEL ROUND BAR	A-36	KILSBY-ROBERTS
1	2	154-583-06	ASSEMBLY		
NO	REQ		DESCRIPTION	MAT'L	

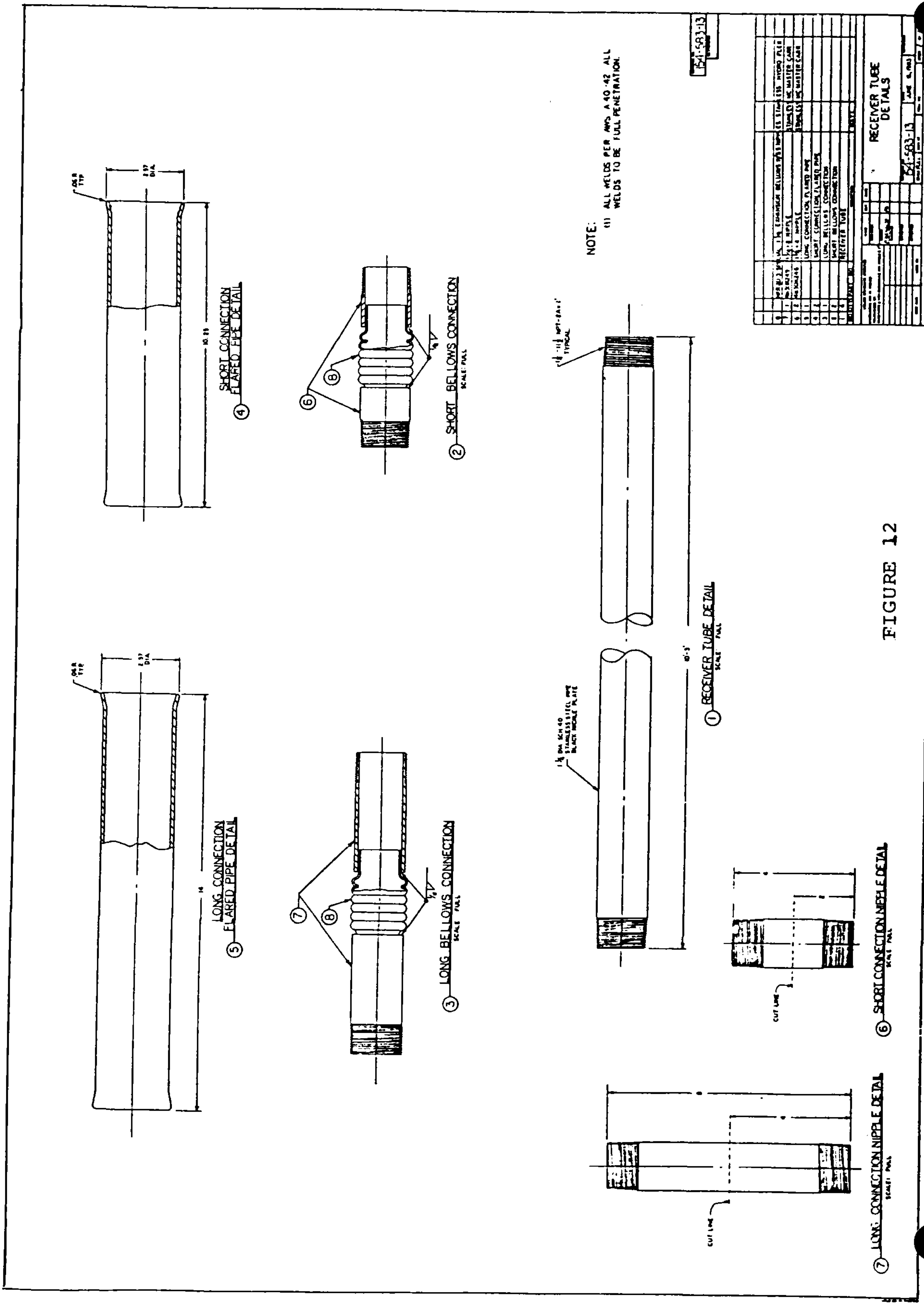
END COLLECTOR SUPPORT AXLE

154-583-06 7-15-83

SCALE FULL SHEET 1 OF 1

MEGA ANALYTICAL RESEARCH SERVICES, INC. SILVER SPRING, MD.

FIGURE 11

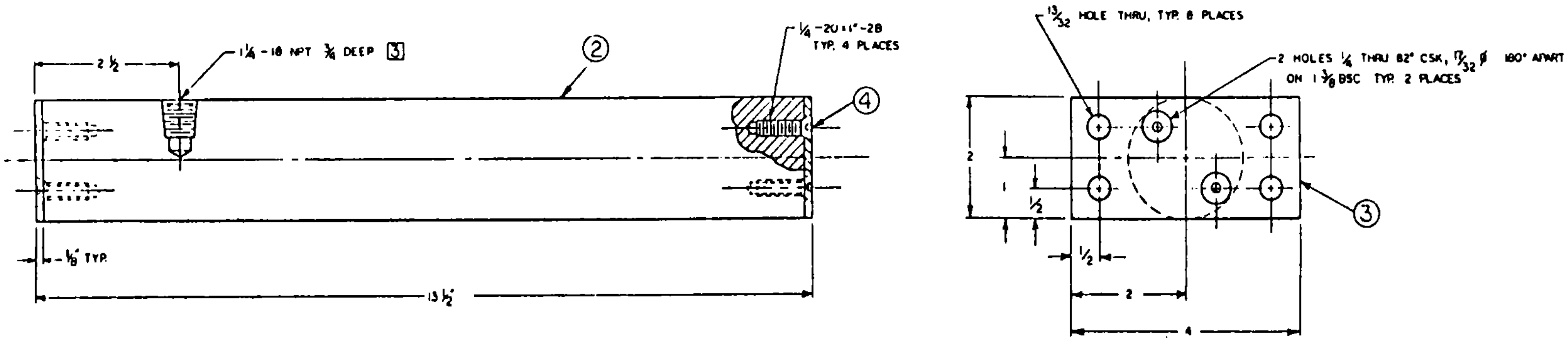


NOTE:
(1) ALL WELDS PER AWS A 40-42 ALL WELDS TO BE FULL PENETRATION.
TSI-583-13
RECEIVER TUBE DETAILS
4 SHORT CONNECTION FLARED PIPE DETAIL
2 SHORT BELLOWS CONNECTION
5 LONG CONNECTION FLARED PIPE DETAIL
3 LONG BELLOWS CONNECTION
1 RECEIVER TUBE DETAIL
6 SHORT CONNECTION NIPPLE DETAIL
7 LONG CONNECTION NIPPLE DETAIL
CUT LINE

FIGURE 12

NOTES

1. REMOVE ALL BURRS & SHARP EDGES TO .010 R.
2. FINISH WITH (1) COAT ZINC CHROMATE AND (1) COAT WHITE EPOXY PAINT
3. 1/4 - 18 TAPPED HOLE ON 1 OF THE 2 AXLES.



(1) ASSEMBLY

4	AR		1/4"-20 x 3/4" FLAT HD HEX SOCKET CAP SC	CRES		
3	AR		1/8" STEEL PLATE	A-36		
2	AR		2" Ø STEEL ROUND BAR	A-36	KILSBY-ROBERTS	
1	2		ASSEMBLY 'A' W/ THREADS 'B' W/O THREADS			

CENTER COLLECTOR SUPPORT AXLE

DRAWN: C. PRATHER

DWG NO. 154-583-05 DATE 7-13-83

SCALE FULL SHEET 1 OF 1

MERA ANALYTICAL RESEARCH SERVICES, INC. SILVER SPRING, MD.

154-583-05

FIGURE 13

REQUEST FOR ADVANCE OR REIMBURSEMENT

(See instructions on back)

Approved by Office of Management and Budget, No. 80-R0183

PAGE OF PAGES

1. TYPE OF PAYMENT REQUESTED
a. "X" one, or both boxes: ☐ ADVANCE ☒ REIMBURSEMENT
b. "X" the applicable box: ☒ FINAL ☐ PARTIAL

2. BASIS OF REQUEST: ☒ CASH ☐ ACCRUAL

3. FEDERAL SPONSORING AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH THIS REPORT IS SUBMITTED
U. S. Department of Energy

4. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER ASSIGNED BY FEDERAL AGENCY
DE-FG01-81CS15072

5. PARTIAL PAYMENT REQUEST NUMBER FOR THIS REQUEST
#5

6. EMPLOYER IDENTIFICATION NUMBER
52-0849829

7. RECIPIENT'S ACCOUNT NUMBER OR IDENTIFYING NUMBER

8. PERIOD COVERED BY THIS REQUEST
FROM (month, day, year) TO (month, day, year)

9. RECIPIENT ORGANIZATION
Name: Mega Engineering
Number and Street: 10800 Lockwood Drive
City, State and ZIP Code: Silver Spring, MD 20901

10. PAYEE (Where check is to be sent is different than item 9)
Name:
Number and Street:
City, State and ZIP Code:

11. COMPUTATION OF AMOUNT OF REIMBURSEMENTS/ADVANCES REQUESTED

PROGRAMS/FUNCTIONS/ACTIVITIES ►		(a)	(b)	(c)	TOTAL
a. Total program outlays to date	(As of date)	$ 58,240.00	$ 4,643.05	$	$ 62,883.05
b. *Less:* Cumulative program income					
c. Net program outlays (*Line a minus line b*)					
d. Estimated net cash outlays for advance period					
e. Total (*Sum of lines c & d*)					
f. Non-Federal share of amount on line e					
g. Federal share of amount on line e					
h. Federal payments previously requested					
i. Federal share now requested (*Line g minus line h*)					34,182.95
j. Advances required by month, when requested by Federal grantor agency for use in making prescheduled advances	1st month				
	2nd month				
	3rd month				

12. ALTERNATE COMPUTATION FOR ADVANCES ONLY

a. Estimated Federal cash outlays that will be made during period covered by the advance	$
b. *Less:* Estimated balance of Federal cash on hand as of beginning of advance period	
c. Amount requested (*Line a minus line b*)	$

13. CERTIFICATION

I certify that to the best of my knowledge and belief the data above are correct and that all outlays were made in accordance with the grant conditions or other agreement and that payment is due and has not

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL: [signature]

DATE REQUEST SUBMITTED: 10/15/83

TYPED OR PRINTED NAME AND TITLE: Richard E. Dame, Ph.D., P.E.

TELEPHONE (AREA CODE, NUMBER, EXTENSION)

FEDERAL CASH TRANSACTIONS REPORT

(See instructions on the back. If report is for more than one grant or assistance agreement, attach completed Standard Form 272-A.)

Approved by Office of Management and Budget, No. 80-

1. Federal sponsoring agency and organizational element to which this report is submitted: U.S. Department of Energy

2. RECIPIENT ORGANIZATION

Name: Richard E. Dame
MEGA Engineering

Number and Street: 10800 Lockwood Drive

City, State and ZIP Code: Silver Spring, MD 20901

3. FEDERAL EMPLOYER IDENTIFICATION NO.:

4. Federal grant or other identification number: CS15072

5. Recipient's account number or identifying number: DE-FG01-[illegible]CS15

6. Letter of credit number:

7. Last payment voucher number: #3

Give total number for this period

8. Payment Vouchers credited to your account:

9. Treasury checks received (whether or not deposited):

10. PERIOD COVERED BY THIS REPORT

FROM (month, day, year): | TO (month, day, year):

11. STATUS OF FEDERAL CASH *(See specific instructions on the back)*		
	a. Cash on hand beginning of reporting period	$ 58,240.00
	b. Letter of credit withdrawals	
	c. Treasury check payments	4,643.05
	d. Total receipts (*Sum of lines b and c*)	62,883.05
	e. Total cash available (*Sum of lines a and d*)	
	f. Gross disbursements	
	g. Federal share of program income	
	h. Net disbursements (*Line f minus line g*)	
	i. Adjustments of prior periods	
	j. Cash on hand end of period	$

12. THE AMOUNT SHOWN ON LINE 11J, ABOVE, REPRESENTS CASH REQUIREMENTS FOR THE ENSUING ___ Days	13. OTHER INFORMATION	
	a. Interest income	$
	b. Advances to subgrantees or subcontractors	$

14. REMARKS (*Attach additional sheets of plain paper, if more space is required*)

15. CERTIFICATION

I certify to the best of my knowledge and belief that this report is true in all respects and that all disbursements have been made for the purpose and conditions of the grant or agreement	AUTHORIZED CERTIFYING OFFICIAL	SIGNATURE / TYPED OR PRINTED NAME AND TITLE	DATE REPORT SUBMITTED / TELEPHONE (Area Code, Number, Extension)
		Richard E. Dame, Ph.D., P.E. President, Mega Engineering	(301)681-6903

THIS SPACE FOR AGENCY USE

272-102

STANDARD FORM 272 (7-76)
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