SCHWARZ Consulting, Inc.
Gerhard Schwarz
33020 Lake Road
Avon Lake, Ohio 44012
Tel.: (216)-933-9340
July 16, 1996

DOE/CE/15400--T16

U.S. Department of Energy
Grant No. DE-FG01-92CE15400
Continuous casting and inside rolling
of round billets for seamless pipe

Final Technical Report

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

BT final
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Content

Description:	Page:
1. Short Description of the Invention.	1 to 5
2. History of the Project Development and Progress.	6 to 9
3. Phase I, Description and Investigation.	10 to 14
4. Phase II, Description and Work Completed.	15 to 18
5. Experimental Metal Casting.	19 to 29
6. Required Additional Work	30
7. Inspection of the Drive Cluster Assembly.	31 to 51
8. Summary of the Correspondence with the DOE.	52

1. Short Description of the Invention.

The invention relates to a patented process and to a motor driven mandrel apparatus (Patent No. 4,546,816) which has the property to roll without slip (or friction) or to roll with controlled friction on the inside surface of a non rotating hollow round. Each point on the circumferential surface of the mandrel describes a hypocycloidal curve or a curve with a hypocycloidal characteristic during the operation of the mandrel.

Page 3 shows schematically the principle of the invention,

Page 4 shows the principle applied to a stable mandrel drive,

Page 5 shows the engineering of the mandrel drive based on the above theory,

where:

d is the diameter of the mandrel,

D is the inside diameter of the hollow round,

r_1 and r_2 is the eccentricity,

S is the distance to the outside mandrel surface,

a , b and c are points on the described arcs.

The rolling property of the mandrel surface is maintained by eccentrics with defined eccentricity and predetermined angular velocities and direction of rotation of the two drive shafts. The characteristic of the described hypocycloidal curve is that the length of the arc 'ac' is equal to the length of the arc 'bc'.

Since the mandrel has an inside and outside wall with a gap for cool water flow of thickness 'S', the hypocycloidal curve is translated to the outside diameter of the mandrel. But the translated curve is not a true hypocycloid and therefore the respective length of the arcs are not equal. To correct the rolled arc on the casting, two independent drives with rotational speed control are required for the operation of the mandrel. With this drive arrangement the mandrel can control the inside deformation of the hollow round with either zero friction (compression only) or forward or backward friction (compression and shear).

Considering a one motor drive only, the calculated friction factor on the casting surface for the dimensions chosen for the test mandrel is $\mu = .055$, see page 10.

The configuration of the mandrel could be cylindrical or tapered or it could be combination of cylindrical and tapered sections over the length of the mandrel. The combination cylindrical/tapered sections has two main functions:

- a) remove the heat from the inner annulus of the casting, and
- b) control the amount of deformation, as well as the deformation pattern and deformation rate of the cast steel.

The application of the mandrel will be for the continuous casting of near-net-shape steel piping for which it is essential that the friction between mandrel and hot casting is zero or controlled minimal. Friction in combination with the rolling pressure on the sensitive thin inner solidified skin would tear the inner annulus resulting in break outs or in commercially not acceptable inner defects of the finished pipe.

The selected drive control and rolling speed of the mandrel will be determined by the heat removal rate and control of the rolling force for the deformation of the steel.

Additional applications are anticipated for the casting or manufacturing of non-ferrous or plastic tubing or other mechanical components with circular inside configuration.

ROTATION OF SHAFTS

☉ ECCENTRIC DRIVE SHAFT

☉ CONCENTRIC DRIVE SHAFT

LIQUID METAL

MOMENTARY GAP

SOLIDIFIED METAL

CLUSTER ASSEMBLY OF DRIVE

2. History of the Project Development and Progress.

(For additional information see also the quarterly reports)

The application for Federal Assistance was submitted to the U.S. Department of Energy (DOE) on February 18, 1992.

The scope of the project was to build and test the machinery for the continuous casting of steel tubing and other related applications.

The project included:

1) Funding by the DOE to build the machinery,	\$83,902.00
2) Study and testrun the machinery under a grant from the Ohio Thomas Edison Program,	\$46,187.50
(The study was to be done by Dr. Spring of the Cleveland State University, CSU, at the Cleveland Advanced Manufacturing Center of CSU)	
3) Provide all engineering, coordination, travel and general expenses by SCHWARZ Consulting, Inc., estimated	\$40,000.00

The DOE-Grant was awarded 3/12/92 for \$83,902 and for a Budget and Project Period from 3/12/91 to 3/11/94.

The Grant was extended through 9/5/95 on 4/20/94.

On October 24, 1995 I asked for another extension through May 1996. This was verbally acknowledged by the DOE on January 23, 1996.

Towards the end of 1992 it was apparent that no Ohio Thomas Edison Fund money would be available and the Project was separated into two phases, Phase I and Phase II.

Phase I was to build and test a bench model for the mandrel drive only. The model was intended for the investigation of the drive and also for demonstration purposes. After successful operation of the model drive, the parts would be reused for Phase II, the test stand.

Phase I Progress:

The engineering was completed in December of 1992 and the order was placed March 11, 1993 with promised delivery of 12 to 16 weeks.

The machinery was delivered early December 1993. The eccentric drive cluster was badly out tolerances and the new replacement parts were delivered by the manufacturer in the middle of November 1994.

The drive did not perform as expected and the cluster arrangement was redesigned.

An order for the new design was placed April 20, 1995 with promised delivery of 6 to 8 weeks.

The new drive was delivered early September 1995 and is now used in the bench model and for the assembly of the test stand mandrel.

Phase II Progress:

In September of 1993 I was contacted by Mr. Larry Orihill, Technology Application Engineer for the Cleveland Advanced Manufacturing Program (CAMP) at the Lorain Community College inquiring about this project. He had of a letter from Terry M. Levinson, Director , Inventions and Innovation Division, Office of National Programs Energy Efficiency and Renewable Energy to David G. Thomas Graves of CAMP in Cleveland, dated August 23, 1993 asking for assistance on this project.

I had meetings with CAMP representatives on September 13, 1994 and October 17, 1994 to discuss the next steps. It was decided to start with Phase II.

NIST Great Lakes Manufacturing Learning Center at the Cuyahoga Community College in Cleveland would manufacture all parts for the mandrel except the parts used at the bench model; SCHWARZ Consulting, Inc. would find a manufacturer for the frame and would purchase all commercial items for the mandrel to be assembled at the Learning Center.

An order was placed with CAMP on November 15, 1994 with promised delivery by summer 1995. The order for the manufacturing of the supporting frame was placed March 3, 1995, promised delivery 10 to 12 weeks.

Early May 1995 the Manufacturing Learning Center informed me that they could manufacture only certain machine made parts, approximately one-half of the order (see Page 9). A short time later I was also told by the Manufacturing Learning Center that there would be no space for the mandrel assembly because of planned machine park expansion. An order for the manufacturing of the remaining parts was placed with a local machine shop on June 28, 1995 with promised delivery of six weeks. Meanwhile I made preparations to assemble the mandrel at my facility.

The support frame was delivered early February 1996.

By the middle of December I could pick up the first parts at the Learning Center in Cleveland and the last part was ready by March 12, 1996.

I prepared subassemblies of the mandrel at my shop but it soon became apparent that I was not prepared for the final assembly because of lack of heavy tools (crane, wrenches etc.).

The machine shop completed their parts of the mandrel by early March.

I made arrangements with the machine shop owner to assemble the mandrel at the shop with the help of a trained mechanic. The final assembly was done at this shop the last two weeks in March of 1996

May 15, 1995

Mr. Gerhard Schwarz
Schwarz Consulting, Inc.
33020 Lake Road
Avon Lake, Ohio 44012

Dear Gerhard:

This letter confirms today's telephone conversation regarding your mandrel project with the GLMTC and CAMP (CAMP Project # GO 1500).

The Manufacturing Learning Center at Cuyahoga Community College is in the process of manufacturing twenty-eight (28) parts on Table #1 of our 11-9-94 Quotation at a cost of \$10,661.30. In addition, the MLC will make a new eccentric drive shaft for \$1,206.30 and lap in the eccentric drive for \$650.00 based on our quotation of 4-24-95.

The MLC does not have the capability to machine and / or weld the nine (9) parts on table #2 of the 11-9-94 Quotation.

It is our recommendation to have these nine (9) parts reviewed by Advanced Design Industries in Lorain, Ohio. I believe they are building your test stand frame work and they have the capability to machine and weld these parts.

Don Kresnye, MLC Director, has expressed an interest in assembling the complete mandrel. We would be happy to quote the mandrel assembly at the appropriate time.

If additional information is required about your project, please do not hesitate to contact me at (216) 365-5222 extension 7026. Thank you.

Yours Truly,

Larry Orihill
Technology Application Engineer

cc: John Laskowski GLMTC
Don Kresnye MLC

3. Phase I, Description and Investigation

To obtain the rolling property of the mandrel, the ratio of the eccentrics must be an even number. The concentric and eccentric drive shaft must rotate in opposite direction to each other and must have a speed ratio corresponding to the even number.

For the mandrel drive the eccentric dimensions are:

$$r_1 = 2.375''$$

$$r_2 = .296875''$$

The ratio is $2.375 : .296875 = 8$ that is,

for one rotation of the eccentric drive shaft the concentric drive shaft must make eight rotations but in opposite direction.

Other eccentrics could be tried on the bench model, but the cluster assembly and eccentric drive shaft have to be replaced.

Selection of the eccentric dimensions determines to a great deal the diameter of the mandrel. Since the diameter of the test mandrel has tapered sections, the diameter range is from 8.4063" to 9.663". Driving both shafts with one motor and gear drive, the ratio of the gear drive must be 8:1, but no correction to the mandrel surface can be done and considering a 9" mandrel diameter, the calculated friction between mandrel surface and casting surface has a friction factor of $\mu = .055$.

The mandrel speed is determined mostly by the heat removal rate and the required rolling force, but also the retention rate of the solidified steel must be considered. In the gap area (see page 5) the solidified shell is momentarily not supported by the mandrel. If the none supporting time exceeds the retention rate of the solidified steel a breakout will occur. Considering all influences, calculations show that the mandrel speed should be in the 600 to 800 rollings per minute range for an efficient and save operation of a production mandrel.

The gear drive arrangement selected for the bench model (see dwg.: ARRG'T. NO.2, Page 13) has a rolling speed from 18 to 367 rollings per minute with a drive motor of 1750 rotations per minute and a speed ratio of the motor of 20:1. For a two motor drive again with 1750 rotations per minute and a speed ratio of 20:1 for each motor, the speed range is from 166 to 1094 rollings per minute.

The bench model is designed for one and two motor operation but also can be operated manually in lieu of a one motor operation.

The mandrel for the test stand is designed for a two motor drive where each motor is controlled manually and the relation of the speeds will be controlled by a hand held tachometer. A more sophisticated control would be desirable and might be necessary.

The bench model was manufactured and assembled by a local machine shop. Upon completion it was not possible to obtain any movement of the machinery. Investigations indicated that the cluster assembly (see page 5 and 36) of the drive was jamming. I had the cluster assembly checked by the Great Lakes Manufacturing Learning in Cleveland for tolerance accuracy.

Their findings are enclosed as part 7. **Inspection of the Drive Cluster Assembly.** Camp provided a quotation to manufacture new parts (see page 50 and 51), but when I confronted the manufacturer with the data, he agreed to supply replacement parts. The new parts showed some improvement but it was not possible to achieve running condition. The Great Lakes Manufacturing Learning Center tried to lap in the drive parts but with little success.

For a successful operation of the mandrel drive the four eccentric pins must rotate freely within the confinement of the pinholders of the cluster assembly. When rotating the concentric shaft the cluster assembly rotates accordingly and together with the rotation of the eccentric shaft provide the rotation of the eccentric pins for the rolling movement of the outside diameter.

The original parts of the cluster assembly were manufactured individually and apparently the manufacturer did not have the precision machinery to hold the tolerances.

I redesigned the cluster assembly by combining the pinholders Det 8 BTM, page 43 and Det 8 Top, page 45 (item 8 of the drawing) to one unit and the pinholders Det 6 AB, page 47 and Det 6 C-D, page 49 (item 6 and 7 of the drawing) to another unit. Each unit was machined as one piece. I eliminated the split bushings, item 37 and the bushings item 38 and insisted on computer controlled machinery for the manufacturing of the pins, which still have to be manufactured individually. The pins are now running steel on steel in the pinholders but have grease lubrication. For prolonged operation a thin ARMOLOY coat (Manufacturer: ARMOLOY of Western Pennsylvania, Inc.) is considered.

The new unit was installed in the bench model and was working if the model was operated manually and sufficient force applied to turn the gear shaft, item 17. But when I connecting the gear shaft to the available 1/3 hp-1725 rpm electric motor, the motor stalled.

Calculations showed that the motor torque on the sprocket, item 26 was 53.36 inch-pounds or the force on the 5.375 inch pitch diameter sprocket to turn the gear shaft was approximately 20 pounds. I used a 6 inch long wrench for turning the gear shaft, item 17. The force I had to apply was 12 pounds which is a torque of 72 inch-pounds on the gear shaft as compared to the available motor torque of 53.36 inch-pounds.

I have been trying to reduce the internal resistance of the cluster assembly by applying a coarse grinding and lapping compound which, which shows improvement. I am continuing this application with a finer compound and will include other rotating parts of the bench model such as eccentric shaft, gears and gear shafts until I have sensitive control of the mandrel drive.

It is obvious that in the future, the design and manufacturing of the mandrel drive should be given special attention.

The 1/3 hp motor I replaced with 1 hp-1750 rpm motors which have a 20:1 speed control.

I have contacted several instrument manufacturer for an instrument which could be attached to the to the inner mandrel wall, item 2. If such instrument could plot the movement of the diameter, the plotted curve (hypocycloidal or other) could be analyzed or compared to another curve and used for the control of the mandrel.

As yet I have not found such instrument on the marked.

Page 14 shows pictures of the bench model:

- a) and b) show the mandrel drive assembly. The drive assembly can also be seen on the pictures of the mandrel assembly, Page 17b.
- c) shows the bench model without the inner mandrel wall, item 2. The model has a one motor drive and the speed control box can be seen on the bench.
- d) shows the two motor drive. One half of the inner mandrel wall, item 2, is removed. The hand held tachometer which, will be tried for the control of the two motors is on the bench.

a

b

c

d

4. Phase II, Description and Work Completed.

The Grant was approved for building the test stand. Originally this test stand was to be investigated by an outside investigator under a grant from the Ohio Thomas Edison Program.

The test stand consists of two arrangements:

- a) the mandrel and
- b) the mandrel support frame.

To complete the test stand assembly for metal casting, the outside cooling and withdrawal arrangement has to be added (not part of the Grant).

a) The mandrel.

Originally it was planned to investigate the mandrel surface by an arrangement of load cells mounted on a carriage which traveled vertically on the support frame. With this arrangement it would have been possible to measure the amount and the direction of the forces on the mandrel surface. But by separating the Grant into Phase I and Phase II the bench model was build instead.

Drawing MAN-ARRGT on page 16 shows the mandrel design.

The mandrel was assembled in a local machine shop according to this drawing and the necessary corrections and improvements were done during the assembly. It was found during the assembly that the spring arrangement at the stabilizer plug (items 29, 23, 30 and 56) and the cool water transfer (items 73 and 74) have to be redesigned (see also page 17c). All parts were checked for free movement during the assembly.

Photos on page 17 show the mandrel during the assembly in the shop.

The mandrel was disassembled and is now in storage.

b) The support frame.

Drawing FRAME-ARRGT on page 18 shows the arrangement of the frame.

The frame was assembled in the shop except for adding the extension (item 13 and 15) and the actuators (item 34) because of restricted height. Some corrections had to done and the parts were marked for reassembly in the future.

Since the mandrel was not available and could not be installed, the mandrel drive (items 14, 17, 45 and 46) was not installed. The (2) -2 hp mandrel drive motors, item 40 have not been purchased.

In order to run the mandrel for testing purpose only the bench model motors can be used.

The frame was shipped disassembled and is now in storage.

BILL OF MATERIAL					
ITEM NO.	DESCRIPTION	MATERIAL	REMARKS	QUANTITY	DETAIL DRAWING
1	CONCENTRIC DRIVE SHAFT	STEEL	1/2" DIA. X 12' 0" LONG	1	MAN-DETA 1
2	DRIVE SPOCKET	"	1/2" DIA. X 12' 0" LONG	1	"
3	HOUSING (WELDMENT)	"	"	1	"
4	MOLD TURNING 9" O.D. 1/2" I.D. 1/2" L.G.	SEPORO	"	33	"
5	HOLDING PLATE	STEEL	"	1	"
6	BEARING SPACER	"	"	1	"
7	MANDREL HANGER - HALF (WELDMENT)	"	"	1	"
8	MANDREL HANGER - HALF (WELDMENT)	"	"	1	"
9	SPOCKET HOLDER	"	"	1	"
10	MOLD HOLDER	"	"	1	"
11	DRIVE SUPPORT RING	"	"	1	"
12	1/2" STANDARD PIPE - 8' 1/2"	"	"	2	"
13	MANDREL MOLD	"	"	1	"
14	WATER GAP SPACER	"	"	1	"
15	WATER GAP SPACER	"	"	1	"
16	MANDREL WALL EXTENSION	"	"	1	"
17	BEARING SUPPORT	"	"	1	"
18	WEAR RING - 2" DIA.	"	"	1	"
19	MANDREL ELECTRIC DRIVE SHAFT	"	"	1	"
20	STABILIZER PLUG WALL (WELDMENT)	"	"	1	"
21	BEARING HOLDER	"	"	1	"
22	SPRING WILDER	"	"	1	"
23	BEARING SUPPORT	"	"	1	"
24	THRUST BEARING SUPPORT	"	"	1	"
25	WEAR RING	"	"	1	"
26	WEAR RING	"	"	1	"
27	GUIDE RING	"	"	1	"
28	HEAVY COIL	"	"	1	"
29	SPRING SUPPORT	"	"	1	"
30	COLD WATER DISTRIBUTOR	"	"	1	"
31	STANDARD PLUG	"	"	1	"
32	SPRING ADJUSTMENT NUT	"	"	1	"
33	STANDARD PLATE KEY 1/2" x 3/4" x 5"	"	"	1	"
34	BEARING SPACER	"	"	1	"
35	END PLATE	"	"	1	"
36	1/2" STANDARD PIPE - 12' 1/2"	"	"	1	"
37	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
38	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
39	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
40	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
41	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
42	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
43	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
44	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
45	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
46	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
47	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
48	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
49	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
50	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
51	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
52	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
53	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
54	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
55	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
56	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
57	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
58	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
59	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
60	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
61	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
62	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
63	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
64	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
65	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
66	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
67	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
68	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
69	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
70	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
71	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
72	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
73	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
74	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
75	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
76	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
77	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
78	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
79	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
80	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
81	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
82	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
83	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
84	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
85	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
86	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
87	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
88	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
89	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
90	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
91	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
92	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
93	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
94	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
95	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
96	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
97	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
98	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
99	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"
100	JOHNSON HEAVY DUTY - SERIES 3/4" HR AS SHOWN IN FIG. 3 - INLET AND OUTLET 5" DIA. HR AS SHOWN IN FIG. 3 NOT REQUIRED - PLUS TWO THREAD	"	"	1	"

SCHWARZ CONSULTING, INC.
AVON LAKE, OHIO

TEST STAND
HYDROLOGICAL MANIPULATOR
CROSS SECTION - GENERAL ARRANGEMENT
MAN - ARRGT

a

b

c

d

IFRAME-ARRGT.

BILL OF MATERIAL

DR. NO.	DESCRIPTION	MANUAL R.	DETAILS
1	SUBPUMP - BOTTOM (INDEPENDENT)	212	4 APPROX
2	SUBPUMP - BOTTOM (INDEPENDENT)	"	53 DETAIL 3
3	SUBPUMP - TOP (INDEPENDENT)	"	49
4	SUBPUMP - TOP (INDEPENDENT)	"	47
5	UPPER CROSS BAR (INDEPENDENT)	"	52
6	UPPER CROSS BAR (INDEPENDENT)	"	53
7	LOWER CROSS BAR (INDEPENDENT)	"	54
8	LOWER CROSS BAR (INDEPENDENT)	"	55
9	LOWER CROSS BAR (INDEPENDENT)	"	56
10	LOWER CROSS BAR (INDEPENDENT)	"	57
11	LOWER CROSS BAR (INDEPENDENT)	"	58
12	LOWER CROSS BAR (INDEPENDENT)	"	59
13	LOWER CROSS BAR (INDEPENDENT)	"	60
14	LOWER CROSS BAR (INDEPENDENT)	"	61
15	LOWER CROSS BAR (INDEPENDENT)	"	62
16	LOWER CROSS BAR (INDEPENDENT)	"	63
17	LOWER CROSS BAR (INDEPENDENT)	"	64
18	LOWER CROSS BAR (INDEPENDENT)	"	65
19	LOWER CROSS BAR (INDEPENDENT)	"	66
20	LOWER CROSS BAR (INDEPENDENT)	"	67
21	LOWER CROSS BAR (INDEPENDENT)	"	68
22	LOWER CROSS BAR (INDEPENDENT)	"	69
23	LOWER CROSS BAR (INDEPENDENT)	"	70
24	LOWER CROSS BAR (INDEPENDENT)	"	71
25	LOWER CROSS BAR (INDEPENDENT)	"	72
26	LOWER CROSS BAR (INDEPENDENT)	"	73 DETAIL 3
27	LOWER CROSS BAR (INDEPENDENT)	"	74
28	LOWER CROSS BAR (INDEPENDENT)	"	75 DETAIL 4
29	LOWER CROSS BAR (INDEPENDENT)	"	76
30	LOWER CROSS BAR (INDEPENDENT)	"	77
31	LOWER CROSS BAR (INDEPENDENT)	"	78
32	LOWER CROSS BAR (INDEPENDENT)	"	79
33	LOWER CROSS BAR (INDEPENDENT)	"	80
34	LOWER CROSS BAR (INDEPENDENT)	"	81
35	LOWER CROSS BAR (INDEPENDENT)	"	82
36	LOWER CROSS BAR (INDEPENDENT)	"	83
37	LOWER CROSS BAR (INDEPENDENT)	"	84
38	LOWER CROSS BAR (INDEPENDENT)	"	85
39	LOWER CROSS BAR (INDEPENDENT)	"	86
40	LOWER CROSS BAR (INDEPENDENT)	"	87
41	LOWER CROSS BAR (INDEPENDENT)	"	88
42	LOWER CROSS BAR (INDEPENDENT)	"	89
43	LOWER CROSS BAR (INDEPENDENT)	"	90
44	LOWER CROSS BAR (INDEPENDENT)	"	91
45	LOWER CROSS BAR (INDEPENDENT)	"	92
46	LOWER CROSS BAR (INDEPENDENT)	"	93
47	LOWER CROSS BAR (INDEPENDENT)	"	94
48	LOWER CROSS BAR (INDEPENDENT)	"	95
49	LOWER CROSS BAR (INDEPENDENT)	"	96
50	LOWER CROSS BAR (INDEPENDENT)	"	97
51	LOWER CROSS BAR (INDEPENDENT)	"	98
52	LOWER CROSS BAR (INDEPENDENT)	"	99
53	LOWER CROSS BAR (INDEPENDENT)	"	100
54	LOWER CROSS BAR (INDEPENDENT)	"	101
55	LOWER CROSS BAR (INDEPENDENT)	"	102
56	LOWER CROSS BAR (INDEPENDENT)	"	103
57	LOWER CROSS BAR (INDEPENDENT)	"	104
58	LOWER CROSS BAR (INDEPENDENT)	"	105
59	LOWER CROSS BAR (INDEPENDENT)	"	106
60	LOWER CROSS BAR (INDEPENDENT)	"	107
61	LOWER CROSS BAR (INDEPENDENT)	"	108
62	LOWER CROSS BAR (INDEPENDENT)	"	109
63	LOWER CROSS BAR (INDEPENDENT)	"	110
64	LOWER CROSS BAR (INDEPENDENT)	"	111
65	LOWER CROSS BAR (INDEPENDENT)	"	112
66	LOWER CROSS BAR (INDEPENDENT)	"	113
67	LOWER CROSS BAR (INDEPENDENT)	"	114
68	LOWER CROSS BAR (INDEPENDENT)	"	115
69	LOWER CROSS BAR (INDEPENDENT)	"	116
70	LOWER CROSS BAR (INDEPENDENT)	"	117
71	LOWER CROSS BAR (INDEPENDENT)	"	118
72	LOWER CROSS BAR (INDEPENDENT)	"	119
73	LOWER CROSS BAR (INDEPENDENT)	"	120
74	LOWER CROSS BAR (INDEPENDENT)	"	121
75	LOWER CROSS BAR (INDEPENDENT)	"	122
76	LOWER CROSS BAR (INDEPENDENT)	"	123
77	LOWER CROSS BAR (INDEPENDENT)	"	124
78	LOWER CROSS BAR (INDEPENDENT)	"	125
79	LOWER CROSS BAR (INDEPENDENT)	"	126
80	LOWER CROSS BAR (INDEPENDENT)	"	127
81	LOWER CROSS BAR (INDEPENDENT)	"	128
82	LOWER CROSS BAR (INDEPENDENT)	"	129
83	LOWER CROSS BAR (INDEPENDENT)	"	130
84	LOWER CROSS BAR (INDEPENDENT)	"	131
85	LOWER CROSS BAR (INDEPENDENT)	"	132
86	LOWER CROSS BAR (INDEPENDENT)	"	133
87	LOWER CROSS BAR (INDEPENDENT)	"	134
88	LOWER CROSS BAR (INDEPENDENT)	"	135
89	LOWER CROSS BAR (INDEPENDENT)	"	136
90	LOWER CROSS BAR (INDEPENDENT)	"	137
91	LOWER CROSS BAR (INDEPENDENT)	"	138
92	LOWER CROSS BAR (INDEPENDENT)	"	139
93	LOWER CROSS BAR (INDEPENDENT)	"	140
94	LOWER CROSS BAR (INDEPENDENT)	"	141
95	LOWER CROSS BAR (INDEPENDENT)	"	142
96	LOWER CROSS BAR (INDEPENDENT)	"	143
97	LOWER CROSS BAR (INDEPENDENT)	"	144
98	LOWER CROSS BAR (INDEPENDENT)	"	145
99	LOWER CROSS BAR (INDEPENDENT)	"	146
100	LOWER CROSS BAR (INDEPENDENT)	"	147
101	LOWER CROSS BAR (INDEPENDENT)	"	148
102	LOWER CROSS BAR (INDEPENDENT)	"	149
103	LOWER CROSS BAR (INDEPENDENT)	"	150
104	LOWER CROSS BAR (INDEPENDENT)	"	151
105	LOWER CROSS BAR (INDEPENDENT)	"	152
106	LOWER CROSS BAR (INDEPENDENT)	"	153
107	LOWER CROSS BAR (INDEPENDENT)	"	154
108	LOWER CROSS BAR (INDEPENDENT)	"	155
109	LOWER CROSS BAR (INDEPENDENT)	"	156
110	LOWER CROSS BAR (INDEPENDENT)	"	157
111	LOWER CROSS BAR (INDEPENDENT)	"	158
112	LOWER CROSS BAR (INDEPENDENT)	"	159
113	LOWER CROSS BAR (INDEPENDENT)	"	160
114	LOWER CROSS BAR (INDEPENDENT)	"	161
115	LOWER CROSS BAR (INDEPENDENT)	"	162
116	LOWER CROSS BAR (INDEPENDENT)	"	163
117	LOWER CROSS BAR (INDEPENDENT)	"	164
118	LOWER CROSS BAR (INDEPENDENT)	"	165
119	LOWER CROSS BAR (INDEPENDENT)	"	166
120	LOWER CROSS BAR (INDEPENDENT)	"	167
121	LOWER CROSS BAR (INDEPENDENT)	"	168
122	LOWER CROSS BAR (INDEPENDENT)	"	169
123	LOWER CROSS BAR (INDEPENDENT)	"	170
124	LOWER CROSS BAR (INDEPENDENT)	"	171
125	LOWER CROSS BAR (INDEPENDENT)	"	172
126	LOWER CROSS BAR (INDEPENDENT)	"	173
127	LOWER CROSS BAR (INDEPENDENT)	"	174
128	LOWER CROSS BAR (INDEPENDENT)	"	175
129	LOWER CROSS BAR (INDEPENDENT)	"	176
130	LOWER CROSS BAR (INDEPENDENT)	"	177
131	LOWER CROSS BAR (INDEPENDENT)	"	178
132	LOWER CROSS BAR (INDEPENDENT)	"	179
133	LOWER CROSS BAR (INDEPENDENT)	"	180
134	LOWER CROSS BAR (INDEPENDENT)	"	181
135	LOWER CROSS BAR (INDEPENDENT)	"	182
136	LOWER CROSS BAR (INDEPENDENT)	"	183
137	LOWER CROSS BAR (INDEPENDENT)	"	184
138	LOWER CROSS BAR (INDEPENDENT)	"	185
139	LOWER CROSS BAR (INDEPENDENT)	"	186
140	LOWER CROSS BAR (INDEPENDENT)	"	187
141	LOWER CROSS BAR (INDEPENDENT)	"	188
142	LOWER CROSS BAR (INDEPENDENT)	"	189
143	LOWER CROSS BAR (INDEPENDENT)	"	190
144	LOWER CROSS BAR (INDEPENDENT)	"	191
145	LOWER CROSS BAR (INDEPENDENT)	"	192
146	LOWER CROSS BAR (INDEPENDENT)	"	193
147	LOWER CROSS BAR (INDEPENDENT)	"	194
148	LOWER CROSS BAR (INDEPENDENT)	"	195
149	LOWER CROSS BAR (INDEPENDENT)	"	196
150	LOWER CROSS BAR (INDEPENDENT)	"	197
151	LOWER CROSS BAR (INDEPENDENT)	"	198
152	LOWER CROSS BAR (INDEPENDENT)	"	199
153	LOWER CROSS BAR (INDEPENDENT)	"	200
154	LOWER CROSS BAR (INDEPENDENT)	"	201
155	LOWER CROSS BAR (INDEPENDENT)	"	202
156	LOWER CROSS BAR (INDEPENDENT)	"	203
157	LOWER CROSS BAR (INDEPENDENT)	"	204
158	LOWER CROSS BAR (INDEPENDENT)	"	205
159	LOWER CROSS BAR (INDEPENDENT)	"	206
160	LOWER CROSS BAR (INDEPENDENT)	"	207
161	LOWER CROSS BAR (INDEPENDENT)	"	208
162	LOWER CROSS BAR (INDEPENDENT)	"	209
163	LOWER CROSS BAR (INDEPENDENT)	"	210
164	LOWER CROSS BAR (INDEPENDENT)	"	211
165	LOWER CROSS BAR (INDEPENDENT)	"	212
166	LOWER CROSS BAR (INDEPENDENT)	"	213
167	LOWER CROSS BAR (INDEPENDENT)	"	214
168	LOWER CROSS BAR (INDEPENDENT)	"	215
169	LOWER CROSS BAR (INDEPENDENT)	"	216
170	LOWER CROSS BAR (INDEPENDENT)	"	217
171	LOWER CROSS BAR (INDEPENDENT)	"	218
172	LOWER CROSS BAR (INDEPENDENT)	"	219
173	LOWER CROSS BAR (INDEPENDENT)	"	220
174	LOWER CROSS BAR (INDEPENDENT)	"	221
175	LOWER CROSS BAR (INDEPENDENT)	"	222
176	LOWER CROSS BAR (INDEPENDENT)	"	223
177	LOWER CROSS BAR (INDEPENDENT)	"	224
178	LOWER CROSS BAR (INDEPENDENT)	"	225
179	LOWER CROSS BAR (INDEPENDENT)	"	226
180	LOWER CROSS BAR (INDEPENDENT)	"	227
181	LOWER CROSS BAR (INDEPENDENT)	"	228
182	LOWER CROSS BAR (INDEPENDENT)	"	229
183	LOWER CROSS BAR (INDEPENDENT)	"	230
184	LOWER CROSS BAR (INDEPENDENT)	"	231
185	LOWER CROSS BAR (INDEPENDENT)	"	232
186	LOWER CROSS BAR (INDEPENDENT)	"	233
187	LOWER CROSS BAR (INDEPENDENT)	"	234
188	LOWER CROSS BAR (INDEPENDENT)	"	235
189	LOWER CROSS BAR (INDEPENDENT)	"	236
190	LOWER CROSS BAR (INDEPENDENT)	"	237
191	LOWER CROSS BAR (INDEPENDENT)	"	238
192	LOWER CROSS BAR (INDEPENDENT)	"	239
193	LOWER CROSS BAR (INDEPENDENT)	"	240
194	LOWER CROSS BAR (INDEPENDENT)	"	241
195	LOWER CROSS BAR (INDEPENDENT)	"	242
196	LOWER CROSS BAR (INDEPENDENT)	"	243
197	LOWER CROSS BAR (INDEPENDENT)	"	244
198	LOWER CROSS BAR (INDEPENDENT)	"	245
199	LOWER CROSS BAR (INDEPENDENT)	"	246
200	LOWER CROSS BAR (INDEPENDENT)	"	247
201	LOWER CROSS BAR (INDEPENDENT)	"	248
202	LOWER CROSS BAR (INDEPENDENT)	"	249
203	LOWER CROSS BAR (INDEPENDENT)	"	250
204	LOWER CROSS BAR (INDEPENDENT)	"	251
205	LOWER CROSS BAR (INDEPENDENT)	"	252
206	LOWER CROSS BAR (INDEPENDENT)	"	253
207	LOWER CROSS BAR (INDEPENDENT)	"	254
208	LOWER CROSS BAR (INDEPENDENT)	"	255
209	LOWER CROSS BAR (INDEPENDENT)	"	256
210	LOWER CROSS BAR (INDEPENDENT)	"	257
211	LOWER CROSS BAR (INDEPENDENT)	"	258
212	LOWER CROSS BAR (INDEPENDENT)	"	259
213	LOWER CROSS BAR (INDEPENDENT)	"	260
214	LOWER CROSS BAR (INDEPENDENT)	"	261
215	LOWER CROSS BAR (INDEPENDENT)	"	262
216	LOWER CROSS BAR (INDEPENDENT)	"	263
217	LOWER CROSS BAR (INDEPENDENT)	"	264
218	LOWER CROSS BAR (INDEPENDENT)	"	265
219	LOWER CROSS BAR (INDEPENDENT)	"	266
220	LOWER CROSS BAR (INDEPENDENT)	"	267
221	LOWER CROSS BAR (INDEPENDENT)	"	268
222	LOWER CROSS BAR (INDEPENDENT)	"	269
223	LOWER CROSS BAR (INDEPENDENT)	"	270
224	LOWER CROSS BAR (INDEPENDENT)	"	271
225	LOWER CROSS BAR (INDEPENDENT)	"	272
226	LOWER CROSS BAR (INDEPENDENT)	"	273
227	LOWER CROSS BAR (INDEPENDENT)	"	274
228	LOWER CROSS BAR (INDEPENDENT)	"	275
229	LOWER CROSS BAR (INDEPENDENT)	"	276
230	LOWER CROSS BAR (INDEPENDENT)	"	277
231	LOWER CROSS BAR (INDEPENDENT)	"	278
232	LOWER CROSS BAR (INDEPENDENT)	"	279
233	LOWER CROSS BAR (INDEPENDENT)	"	280
234	LOWER CROSS BAR (INDEPENDENT)	"	281
235	LOWER CROSS BAR (INDEPENDENT)	"	282
236	LOWER CROSS BAR (INDEPENDENT)	"	283
237	LOWER CROSS BAR (INDEPENDENT)	"	284
238	LOWER CROSS BAR (INDEPENDENT)	"	285
239	LOWER CROSS BAR (INDEPENDENT)	"	286
240	LOWER CROSS BAR (INDEPENDENT)	"	287
241	LOWER CROSS BAR (INDEPENDENT)	"	288
242	LOWER CROSS BAR (INDEPENDENT)	"	289
243	LOWER CROSS BAR (INDEPENDENT)	"	290
244	LOWER CROSS BAR (INDEPENDENT)	"	291
245	LOWER CROSS BAR (INDEPENDENT)	"	292
246	LOWER CROSS BAR (INDEPENDENT)	"	293
247	LOWER CROSS BAR (INDEPENDENT)	"	294
248	LOWER CROSS BAR (INDEPENDENT)	"	295
249	LOWER CROSS BAR (INDEPENDENT)	"	296
250	LOWER CROSS BAR (INDEPENDENT)	"	297
251	LOWER CROSS BAR (INDEPENDENT)	"	298
252	LOWER CROSS BAR (INDEPENDENT)	"	299
253	LOWER CROSS BAR (INDEPENDENT)	"	300
254	LOWER CROSS BAR (INDEPENDENT)	"	301
255	LOWER CROSS BAR (INDEPENDENT)	"	302
256	LOWER CROSS BAR (INDEPENDENT)	"	303
257	LOWER CROSS BAR (INDEPENDENT)	"	304
258	LOWER CROSS BAR (INDEPENDENT)	"	305
259	LOWER CROSS BAR (INDEPENDENT)	"	306
260	LOWER CROSS BAR (INDEPENDENT)	"	307
261	LOWER CROSS BAR (INDEPENDENT)	"	308
262	LOWER CROSS BAR (INDEPENDENT)	"	309
263	LOWER CROSS BAR (INDEPENDENT)	"	310
264	LOWER CROSS BAR (INDEPENDENT)	"	311
265	LOWER CROSS BAR (INDEPENDENT)	"	312
266	LOWER CROSS BAR (INDEPENDENT)	"	313
267	LOWER CROSS BAR (INDEPENDENT)	"	314
268	LOWER CROSS BAR (INDEPENDENT)	"	315
269	LOWER CROSS BAR (INDEPENDENT)	"	316
270	LOWER CROSS BAR (INDEPENDENT)	"	317
271	LOWER CROSS BAR (INDEPENDENT)	"	318
272	LOWER CROSS BAR (INDEPENDENT)	"	319
273	LOWER CROSS BAR (INDEPENDENT)	"	320
274	LOWER CROSS BAR (INDEPENDENT)	"	321
275	LOWER CROSS BAR (INDEPENDENT)	"	322
276	LOWER CROSS BAR (INDEPENDENT)	"	323
277	LOWER CROSS BAR (INDEPENDENT)	"	324
278	LOWER CROSS BAR (INDEPENDENT)	"	325
279	LOWER CROSS BAR (INDEPENDENT)	"	326
280	LOWER CROSS BAR (INDEPENDENT)	"	327
281	LOWER CROSS BAR (INDEPENDENT)	"	328
282	LOWER CROSS BAR (INDEPENDENT)	"	329
283	LOWER CROSS BAR (INDEPENDENT)	"	330
284	LOWER CROSS BAR (INDEPENDENT)	"	331
285	LOWER CROSS BAR (INDEPENDENT)	"	332
286	LOWER CROSS BAR (INDEPENDENT)	"	333
287	LOWER CROSS BAR (INDEPENDENT)	"	334
288	LOWER CROSS BAR (INDEPENDENT)	"	335
289	LOWER CROSS BAR (INDEPENDENT)	"	336
290	LOWER CROSS BAR (INDEPENDENT)	"	337
291	LOWER CROSS BAR (INDEPENDENT)	"	338
292	LOWER CROSS BAR (INDEPENDENT)	"	339
293	LOWER CROSS BAR (INDEPENDENT)	"	340
294	LOWER CROSS BAR (INDEPENDENT)	"	341
295	LOWER CROSS BAR (INDEPENDENT)	"	342
296	LOWER CROSS BAR (INDEPENDENT)	"	343
297	LOWER CROSS BAR (INDEPENDENT)	"	344
298	LOWER CROSS BAR (INDEPENDENT)	"	345
299	LOWER CROSS BAR (INDEPENDENT)	"	346
300	LOWER CROSS BAR (INDEPENDENT)	"	347
301	LOWER CROSS BAR (INDEPENDENT)	"	348
302	LOWER CROSS BAR (INDEPENDENT)	"	349
303	LOWER CROSS BAR (INDEPENDENT)	"	350
304	LOWER CROSS BAR (INDEPENDENT)	"	351
305	LOWER CROSS BAR (INDEPENDENT)	"	352
306	LOWER CROSS BAR (INDEPENDENT)	"	353
307	LOWER CROSS BAR (INDEPENDENT)	"	354
308	LOWER CROSS BAR (INDEPENDENT)	"	355
309	LOWER CROSS BAR (INDEPENDENT)	"	356
310	LOWER CROSS BAR (INDEPENDENT)	"	357
311	LOWER CROSS BAR (INDEPENDENT)	"	358
312	LOWER CROSS BAR (INDEPENDENT)	"	359
313	LOWER CROSS BAR (INDEPENDENT)	"	360
314	LOWER CROSS BAR (INDEPENDENT)	"	361
315	LOWER CROSS BAR (INDEPENDENT)	"	362
316	LOWER CROSS BAR (INDEPENDENT)	"	363
317	LOWER CROSS BAR (INDEPENDENT)	"	364
318	LOWER CROSS BAR (INDEPENDENT)	"	365
319	LOWER CROSS BAR (INDEPENDENT)	"	366
320	LOWER CROSS BAR (INDEPENDENT)	"	367
321	LOWER CROSS BAR (INDEPENDENT)	"	368
322	LOWER CROSS BAR (INDEPENDENT)	"	369
323	LOWER CROSS BAR (INDEPENDENT)	"	370
324	LOWER CROSS BAR (INDEPENDENT)	"	371
325	LOWER CROSS BAR (INDEPENDENT)	"	372
326	LOWER CROSS BAR (INDEPENDENT)	"	373
327	LOWER CROSS BAR (INDEPENDENT)	"	374
328	LOWER CROSS BAR (INDEPENDENT)	"	375
329	LOWER CROSS BAR (INDEPENDENT)	"	376
330	LOWER CROSS BAR (INDEPENDENT)	"	377
331	LOWER CROSS BAR (INDEPENDENT)	"	378
332	LOWER CROSS BAR (INDEPENDENT)	"	379
333	LOWER CROSS BAR (INDEPENDENT)	"	380
334	LOWER CROSS BAR (INDEPENDENT)	"	381
335	LOWER CROSS BAR (INDEPENDENT)	"	382
336	LOWER CROSS BAR (INDEPENDENT)	"	383
337	LOWER CROSS BAR (INDEPENDENT)	"	384
338	LOWER CROSS		

NOTE: AFTER ASSEMBLY AND ALIGNING OF SUPPORT FRAME, DONEL MATCHING, CONTACT SURFACES WITH $\frac{1}{8}$ " DIA. DONEL, PINE ITEM ⑥ AND MARK THE ITEMS FOR DISASSEMBLY, SHIPPING, AND REASSEMBLY. DRAWINGS DO NOT CALL FOR MACHINING OF CONTACT SURFACES, BUT MACHINING OR PLANING SHOULD BE DONE IF NECESSARY FOR ALIGNING. THE RESULTS CHANGES IN OVERALL DIMENSIONS ARE ACCEPTABLE.

TOTAL WEIGHT OF STRUCTURAL - 2,200 lbs.

FOR ARRANGEMENT OF MANDREL SEE PNG: MAN-ARRGT.

REVISION A 2/27/95
ITEMS PURCHASED BY
SOURCE CONTAINING ADDED
REVISION A 2/27/95
ITEM 12 WAS 2 REQ'D.
ITEMS 22 THRU 33 ABOVE

[illegible]

5. Experimental Metal Casting.

In the early stage of my Application for Federal Assistance, Mr. Jack Aellen from the DOE called me on January 21, 1988, asking if tin casting on the prototype model could be added to the project. Mr. Eckhart of the DOE Steel Group suggested the addition, since tin could be cast in an laboratory environment. The request was investigated but it increased the Request for Federal Assistance to \$118,000 and was subsequently taken out of the program.

With future metal casting in mind, I designed the test stand accordingly that even steel casting could be included.

To include metal casting in this project, the outside mold, outside spray cooling and withdrawal of the casting has to be added to the test stand. Drawing STRAND-ARRGT on page 21 shows the additional equipment. The manufacture of this equipment was quoted \$24,590.

Drawing GEN-ARRGT on page 22 shows the completed test stand.

Liquid metal is poured into the opening confined by the mold of the mandrel with 9" diameter and the outside mold with 12" diameter. A solidified inner and outer annulus is formed by the molds. Both are connected by a bridge of solidified steel cooled at the bottom of the molds by spray cooling. The cooled steel bridge is attached to the withdrawal mechanism which lowers both annuli as one unit. The inside cooling and deformation is completed by the mandrel. The outside cooling is completed by water spray. The finished casting has an outside diameter of 12" and an inside diameter of 10 1/4" and is 24" long. The casting can be removed hot from the test stand.

In my meeting with CAMP personnel in September 1994, I was informed that the NIST Great Lakes Manufacturing Technology Center (GLMTC) had purchased a small foundry in 1994 and had it installed in an existing building in Cleveland. The foundry is for investigating rapid aluminum casting. The building is of sufficient height and has the utilities for operating the test stand.

I had another meeting with CAMP personnel on March 27, 1996, regarding the progress of the foundry operation and how it could be utilized for experimental casting on the test stand. The foundry operation had been improved to include steel melting and casting even small batches of 600 pounds as needed for the test stand can be melt.

All commercial steel grades can be melted, such as steel grades for high quality commercial piping.

Also hot metal feeding equipment for the mold opening would be available.

In response to this meeting, CAMP/GLMTC prepared a proposal for casting the test pieces at the foundry, see pages 23 to 29.

May 30, 1996

Mr. Gerhard Schwarz
Consulting Engineer
Schwarz Consulting, Inc.
33020 Lake Road
Avon Lake, Ohio 44012

Dear Gerhard:

In response to our meeting of March 27, 1996, the NIST/Great Lakes Manufacturing Technology Center (GLMTC), a division of the Cleveland Advanced Manufacturing Program (CAMP), is pleased to submit the following proposal for your consideration. The proposal is for a **Project To Continue The Development And Test The Schwarz Patented Hypocyclodial Mandrel For The Continuous Casting Of Near Net Shape Steel Tubing**. This project has been funded by the Department Of Energy under grant # DE-FG01-92CE15400. That grant was to initiate development of this invention.

Mr. Terry Pim, CAMP's Director of Business Development, will be your primary contact person on this project. He will be assisted by Tom Cobett, Manager of the GLMTC's Rapid Casting Facility, and appropriate members of the GLMTC staff.

To accept this proposal and begin work on the project, please fill out the attached **Contract for CAMP/GLMTC Services**, and return it to the address noted on the form.

We are looking forward to assisting you in the continuous development **and the testing** of this high technology hypocyclodial mandrel with significant cost saving potential to the steel and casting industries.

Yours Truly,

Larry Orihill
Technology Application Engineer

cc: Terry Pim CAMP
Tom Cobett Rapid Casting Facility

BACKGROUND

Schwarz Consulting, Inc. has invented a patented, hypocycloidal mandrel for the continuous casting of near net shape steel tubing. This invention has been selected by the Department of Energy as having a very high probability of success in reducing energy costs of up to \$60.00 per ton in manufacturing steel pipe and tubing. In addition, the Department of Energy feels that this invention will improve quality, strength, and manufacturing tolerance of piping production. As a result, Schwarz Consulting had received a grant from the Department of Energy to initiate development of this invention. The grant number was #DE-FG01-92CE15400.

As of April 1, 1996 funds have been expended to manufacture the mandrel and test stand. **Additional funds are required to continue the development and to test this invention.** Mr. Gerhard Schwarz has requested the NIST/Great Lakes Manufacturing Technology Center's Rapid Casting Facility to provide a proposal that will enable further development and the testing of the mandrel itself. The testing will enable Schwarz to evaluate his patented "KIROHR" continuous cast steel pipe process by actually pouring steel and making sections of pipe. Physical tests, metallographic analysis and NDT testing can then be performed on the pipe samples.

The mandrel and test stand are now available for testing. The weight of these two (2) items when assembled is almost two thousand and five hundred pounds (2,500 lbs.) Physical floor dimensions of this assembly are twelve (12) feet high by eight (8) feet long by eight (8) feet deep.

Electric power, recirculating cooling water, and the ability to pour five hundred (500) pounds of molten metal are required **and available** at the GLMTC Rapid Casting Facility. Metal can be poured at the Rapid Casting Facility per required pipe caster specifications as to alloy and hardness to enable accurate evaluation of the "KIROHR" piping process.

PROJECT OBJECTIVE

The purpose of this project is to work with Schwarz Consulting, Inc. in continuing the development and to test the patented hypocycloidal mandrel for the continuous casting of near net shape steel tubing.

PROJECT BENEFITS

This project will enable Schwarz Consulting, Inc. to continue development and to test this invention in timely fashion and in a cost effective manner. Also, by working with the GLMTC casting facility, **introduction of this invention** to the steel and casting industries will be easier and more readily available.

PROJECT PLAN AND SCHEDULE

Contact Persons:

Terry Pim
Director of Business Development
(216) 432-4198

Tom Cobett
Manager of Rapid Casting Facility
(216) 268-3044

Larry Orihill
Technology Application Engineer
(216) 365-5222

Estimated Start Date: Four (4) to Six (6) weeks after receipt of the Contract for CAMP/GLMTC Services.

Estimated Project Duration: Six (6) to Eight (8) months.

PROJECT FEE, PAYMENT AND TERMS

Project Cost: \$150,000.00 (NOT TO EXCEED)

Fee Schedule: \$50,000.00 (DOWN PAYMENT)

Balance of time, material and expenses will be invoiced monthly. Work to proceed upon approval of Gerhard Schwarz.

Invoices are payable on receipt.

PROJECT DELIVERABLES

CAMP and the GLMTC will deliver the following to properly evaluate and demonstrate the "KIROHR" Continuous Cast Steel Pipe Process:

- Set up office and work space at the Rapid Casting Facility
- Assemble mandrel components
- Design and build two (2) mandrel drive units
- Design and build oscillating outside mold to achieve proper pipe wall thickness
- Assemble test stand with safety wall around, hood and water sump to collect spray
- Install mandrel, outside and inside mold on test stand, with overhead hoist
- Install mandrel drives on test stand
- Add recirculating water cooling lines to mandrel and test stand
- Design and build receiver tundish with stopper^{*}rod/slide gate above test stand
- Design and build ladle hoist
- Obtain handling equipment for hot pipe
- Operate the mandrel drives and withdrawal carriage
- Test mandrel operation with low temperature metal such as aluminum
- Repeat testing until acceptable pipe is produced
- Disassemble mandrel and repair as necessary
- Test mandrel operation with low carbon steel
- Repeat testing until acceptable pipe is produced
- Run Physical Tests, Metallographic Analysis and NDT on pipe samples
- Prepare final report

Contract for CAMP/GLMTC Services

Client Name: Schwarz Consulting Inc.

Proposal Name: Develop and Test Hypocyclodial Mandrel (II)

Proposal Number: GM 2819

Proposal Summary: The RCF will assist Schwarz in the development and testing of his patented Hypocyclodial Mandrel for the continuous casting of near net shape tubing

Est. Start Date: Four (4) to six (6) weeks after receipt of the Contract for CAMP/GLMTC Services

Est. Project Duration: Six (6) to eight (8) months

Project Cost: \$150,000.00 (Not to Exceed)

Fee Schedule: \$50,000.00 (Down Payment)

Balance of time, material and expenses will be invoiced monthly. Work to proceed upon approval of Gerhard Schwarz.

Accepted by: _____

Title: _____ **Date:** _____

P.O. and Check #: _____ (made out to CAMP)

Note: This instrument contains the entire agreement between the parties and no statement, promises, or inducements made by either party that is not contained in this written contract shall be valid or binding; this contract may not be enlarged, modified, or altered except in writing, signed by the parties and endorsed hereon.

Return to: Maryla Engelking (LMO)
CAMP/GLMTC
Prospect Park Building 4600 Prospect Avenue
Cleveland, OH 44103-4314

Phone: (216) 432-4314
Fax: (216) 361-2091

GLMTC PROJECT ECONOMIC IMPACT WORKSHEET

Company: Schwarz Consulting Inc.

Project: Dev. & Test Mandrel

Proj. #: GM 2819

ersion: 8/93

Location: E:\FORMS\ECONOMIC.FRM

NO.	DESCRIPTION OF ECONOMIC IMPACT ITEMS	Pre-Project (w/proposal)	Post-Project
		AMOUNT	AMOUNT
1.	Enter the dollar value of inventory reduced.		
2.	Enter the dollar amount of one-time capital avoidance.	100,000.00	
3.	Enter the production related cost savings below:		
	a. Production related material savings.	50,000.00	
	b. Production related labor savings.	25,000.00	
	c. Production related overhead savings.	30,000.00	
4.	Enter the steady state non-production cost savings per year.		
5.	Was there an increase in revenue?		
	a. Due to cost reductions?	Yes No	Yes No
	b. Due to product improvements?	Yes No	Yes No
	c. Due to other improvements?	Yes No	Yes No
	d. Revenue increase from now for the 2nd year after implementation.		
6.	List other improvements reducible to an annual dollar impact and enter their amounts in the corresponding cells to the right:		
	a. Improved Quality and Function	25,000.00	
	b.		
	c.		
7.	List improvements not reducible to an annual dollar amount:		
	a.		
	b.		
8.	Calculated comprehensive economic impact index amount:	180,000.00	0.00
9.	Enter the cost to implement project:		
	a. Enter the GLMTC project contract cost:	150,000.00	
	b. Enter the total of other company costs:		
10.	This is the calculated payback period in years.	0.83	??
11.	Estimate the number of jobs created or saved—now as well as in the future—as a result of GLMTC assistance.		

After you have completed a project, fill in the POST-PROJECT column with your client. Ask the client to estimate the anticipated impact over the next year after project implementation.

Great Lakes Manufacturing Technology Center Additional Contract Terms

1. Any changes in the contract will be made only upon mutual agreement of the parties and will be evidenced by a written agreement executed by both parties.
2. CAMP/GLMTC agrees that all its employees and subcontractors will understand and be bound by the provisions of the contract.
3. CAMP/GLMTC and its subcontractors shall be forthright in disclosing all inventions or improvements thereon in its project reports to the Company.
4. The Company, CAMP/GLMTC, and its subcontractors agree that mutually disclosed information will not be made public or to another party without the prior written consent of all the original parties so as to not endanger a potential patent position or reveal information one party considers to be proprietary.
5. The company agrees to allow CAMP/GLMTC to publish nonproprietary results from the project for promotional purposes and for reporting to CAMP/GLMTC government sponsors. CAMP/GLMTC will allow the Company 30 days to review such material for proprietary items which should be excluded in public materials.
6. CAMP/GLMTC agrees to keep complete financial and technical records of progress made on the project. CAMP/GLMTC also agrees to allow the Company access during the CAMP/GLMTC working hours to inspect, copy, and freely use the project records for the Company's purposes.
7. CAMP/GLMTC agrees to comply with all applicable laws and government regulations relating to the project. CAMP/GLMTC and the Company further agree not to take any action in the name of or otherwise on behalf of the other party which would violate applicable laws or government regulations.
8. The implementation of any advice or products provided by CAMP/GLMTC project will be at the sole discretion of the Company's management. CAMP shall be only held accountable for the specific deliverables in the contract and shall not be held accountable for any consequential effects of implementing the deliverables. CAMP cannot therefore share in the increased Company profits, or in the rare case of a negative effect, share or be named party in any losses, lawsuits, or other legal action stemming from company management implementation decisions relative to the contract deliverables.
9. If one party for any reason desires to immediately terminate the contract, then the second party is required to agree to such a termination at a time no greater than sixty days from the date that the original written notice of desired termination is delivered to the second party. If one party for any reason desires to terminate the contract at a date greater than sixty days from the time of notice, but earlier than the stated contract end date, then the second party must agree to termination at the requested date. Payment or refund due either party shall be determined on a pro rata basis according to the amount of work done by CAMP/GLMTC up to the time of termination.
10. In the event that either party breaches any of the terms of the contract, and said breach is not resolved within sixty days after notice thereof to said party, then the other party has the right to terminate the contract effective as of the end of said sixty day period. Should this agreement be terminated for cause by either party, then payment or refund due either party shall be determined on a pro rata basis according to the amount of work done by CAMP/GLMTC up to the time of termination.

Information Disclosure

In-as-much as CAMP and the GLMTC receive public funds, and thus this project is indirectly subsidized, your company may be required to provide project impact data in writing (within a reasonable time from request) during a period of five years following the completion of the project. This data includes, but is not limited to, jobs created, jobs retained, cost savings, increased revenues, and the amount of follow up company investment directly attributable to the project. Such data will be treated confidentially by CAMP and the GLMTC, and will only be used in anonymous summary statistics presented to the State and other benefactors. Any exception to the above data confidentiality rule (such as to provide specific anecdotal material for public speech or a marketing document) will be specifically sought on a case-by-case basis, with your company's approval required for the final wording of any data that may be presented.

6. Required Additional Work.

- a) Improve the performance of the mandrel drive of the bench model. Possibly include an outside investigator for the evaluation.**
- b) Assemble the available test stand for test runs. Test runs should include investigation of the cool water flow. Determine if the hand held tachometer is satisfactory for the control of the mandrel drives to cast acceptable steel samples.**
- c) Manufacture the parts for the outside cooling and withdrawal of the test piece. Install the equipment at the test stand.**
- d) Cast the pipe samples.**

For preparation and casting procedure see enclosed CAMP/GLMTC project plan and schedule dated May 30, 1996 on pages 23 to 29.

7. Inspection of the Drive Cluster Assembly

Enclosed inspection report (pages 34 to 49) by the CAMIP Manufacturing Learning Center shows the tolerance deviations of the individual parts for the drive cluster assembly. With this off drawing tolerance scatter, the drive parts were binding and jamming and the drive assembly could not be used for the mandrel.

**NIST Great Lakes
Manufacturing Technology Center**

2415 Woodland Avenue Cleveland, Ohio 44115
216/987-3200 FAX: 987-3210

January 6, 1994

Mr. Gerhard Schwarz
Schwarz Consulting, Inc.
33020 Lake Road
Avon Lake, Ohio 44012

Dear Gerhard:

The Manufacturing Learning Center is pleased to submit the attached quotation for your consideration.

This quotation is for a **Inspection Measurement Project** for the inspection of Schwarz Consulting, Inc. Test Stand Hypocyclodial Drive Arrangement Details listed in the attached deliverables section. (See attached Quotation).

Upon acceptance, work will begin in the Manufacturing Learning Center 1/18/94.

The total project is \$1526.00 and will be billed to you upon completion.

If you have any questions concerning this quote or need additional information, please feel free to contact me at (216) 987-3204 or (216) 987-3046.

We appreciate the opportunity to assist you in your manufacturing process and look forward to doing business with you in the future.

Sincerely,

Dennis Rosa
Technology Program Manager,
Quality Systems

cc: L. Orihill
E. Kopinsky
D. Kresnye
J. Laskowski
J. Wright

CCC/MRF MANUFACTURING LEARNING CENTER

2415 Woodland Avenue

Cleveland, Ohio 44115

(216) 987-3090

QUOTATION

Quotation #: 020, Proposal #112

Date: 1/6/94

Customer Name & Address: Mr. Gerhard Schwarz
Schwarz Consulting, Inc.
33020 Lake Road
Avon Lake, Ohio 44012
(216) 933-9340

QUANTITY	DESCRIPTION	Price/ each	Total
2	Detail 8 Pinholder	\$ 226	\$ 452
2	Detail 6 Pinholder	\$ 45	\$ 90
4	Detail 9 Eccentric Pin	\$ 246	\$ 984
	PROJECT TOTAL		\$1526.00

Proposed Start Date: 1/18/94

Proposed Completion Date: 1/28/94

Quoted by: *Dennis Rose*

Approved by: *N. J. Kowalski* Date: *1/7/94*

ACCEPTED:
Gerhard Schwarz 1/13/94
SCHWARZ CONSULTING INC.

**NIST Great Lakes
Manufacturing Technology Center**

2415 Woodland Avenue Cleveland, Ohio 44115
216/987-3200 FAX: 987-3210

a Division of **CAMP** Cleveland
Advanced
Manufacturing
Program
an Edison Technology Center

March 3, 1994

Mr. Gerhard Schwarz
Consulting Engineer
Schwarz Consulting Inc.
33020 Lake Road
Avon Lake Road, Ohio 44012

RE: Completion of Quality Manual Development CAMP MLC Project #1141

Dear Mr. Schwarz:

Enclosed please find one (1) copy of the inspection reports summarizing the drawing specifications, the actual dimensions measured, deviations from nominal, and out of tolerance conditions for the 8 parts detailed in our proposal dated January 6, 1994.

The stack ups of the bore locations on the pinholders and the journal locations on the eccentric shafts are causing the binding condition. Pending your review of the out of tolerance conditions on the parts it may be possible for the Manufacturing Learning Center (MLC) to repair the parts per your written instructions. Ed Kopinsky MLC Manufacturing Supervisor, will coordinate with you to develop a proposal if required.

Please do not hesitate to contact me at (216) 987-3204. This submittal constitutes the **Deliverable** as defined in Dennis Rosa's proposal #112 of January 6, 1994.

Very truly yours,

Dennis J. Rosa — 987-3204

Dennis J. Rosa
Technical Program Manager,
Quality Systems

JACK

cc: J. Wright, CAMP/GLMTC 1-216
L. Orihill, LCCC

ED. E. Kopinsky — 987-3090
D. Kresnye

J. Laskowski

John

687-5519 morning
432-5373 afternoon } *CAMP*

March 3, 1994

Jack,

enclosed sketches show more visual the results of your inspection as I understand it. Please have a look at it and let me know if you agree. Feel free to make corrections. Also tell Ed. Hopkins I would like an estimate for the correction and remachining of the parts. I will talk to you after I come back from vacation.

DRIVE CLUSTER ASSEMBLY

CUST SWARZ CONSULTING		Part No. Eccentric Pin Det 9F		Inspector JLW	
Inspection Results				Date 2/24/94	
Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	.747 +.001-0	0.7496	0.0026	0.0016	
2	.747 +.001-0	0.7496	0.0026	0.0016	
3	.747 +.001-0	0.7402	-0.0068	-0.0068	
4	.747 +.001-0	0.7438	-0.0032	-0.0032	
5	0.297 +/- .002	0.2948	-0.0020	-0.0002	
6	.747 +.001-0	0.7396	-0.0074	-0.0074	
7	.747 +.001-0	0.7419	-0.0051	-0.0051	
8	0.297 +/- .002	0.3028	0.0058	0.0038	

CUST SWARZ CONSULTING		Part No. Eccentric Pin Det 9J		Inspector JLW	
		Inspection Results		Date 2/24/94	
Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	.747 +.001-0	0.7498	0.0028	0.0018	
2	.747 +.001-0	0.7496	0.0026	0.0016	
3	.747 +.001-0	0.7408	-0.0062	-0.0062	
4	.747 +.001-0	0.7398	-0.0072	-0.0072	
5	0.297 +/- .002	0.3075	0.0105	0.0085	
6	.747 +.001-0	0.7393	-0.0077	-0.0077	
7	.747 +.001-0	0.7393	-0.0077	-0.0077	
8	0.297 +/- .002	0.3051	0.0081	0.0061	

CUST SWARZ CONSULTING		Part No. Eccentric Pin Det 9Dot		Inspector JLW	
		Inspection Results		Date 2/24/94	
Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	.747 +.001-0	0.7473	0.0003		
2	.747 +.001-0	0.7487	0.0017	0.0007	
3	.747 +.001-0	0.7370	-0.0100	-0.0100	
4	.747 +.001-0	0.7375	-0.0095	-0.0095	
5	0.297 +/- .002	0.2968	-0.0002		
6	.747 +.001-0	0.7397	-0.0073	-0.0073	
7	.747 +.001-0	0.7370	-0.0100	-0.0100	
8	0.297 +/- .002	0.2935	-0.0035	-0.0015	

CUST SWARZ CONSULTING		Part No. Eccentric Pin Det 9Blank		Inspector JLW	
		Inspection Results		Date 2/24/94	
Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	.747 +.001-0	0.7506	0.0036	0.0026	
2	.747 +.001-0	0.7484	0.0014	0.0004	
3	.747 +.001-0	0.7397	-0.0073	-0.0073	
4	.747 +.001-0	0.7408	-0.0062	-0.0062	
5	0.297 +/- .002	0.2950	-0.0020		
6	.747 +.001-0	0.7411	-0.0059	-0.0059	
7	.747 +.001-0	0.7397	-0.0073	-0.0073	
8	0.297 +/- .002	0.2910	-0.0060	-0.0040	

ECCENTRIC PIN DET 9F; 9J; 9DOT & 9BLANK

TRUE SCALE [DWG. DETAIL - 3 (REV. 1) - ITEM 9]

ECCENTRICITY

.297 ±.002 (TYP. DWG.)

TOLERANCE OF ECCENTRICITY

TOLERANCE

SWARZ CONSULTING Inspection Results		Part No. PIN HOLDER DET 8 BTM		J WRIGHT CAMP 2/24/94	
Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	BORE 2.5	ESTABLISH ZERO			
2	.750 +/- .001	0.7565	0.0065	0.0055	
	X2.375 +/- .001	2.3764	0.0014	0.0004	
	Y000 +/- .001	-0.0013	-0.0013	-0.0003	
3	.750 +/- .001	0.7565	0.0065	0.0055	
	X0.0 +/- .001	0.0025	0.0025	0.0015	
	Y2.375 +/- .001	2.3728	-0.0022	-0.0012	
4	.750 +/- .001	0.7566	0.0066	0.0056	
	X-2.375 +/- .001	-2.3707	0.0043	0.0033	
	Y0.00 +/- .001	-0.0012	-0.0012	-0.0002	
5	.750 +/- .001	0.7568	0.0068	0.0058	
	X0.0 +/- .001	0.0038	0.0038	0.0028	
	Y-2.375 +/- .001	-2.3746	0.0004	+++	
6	4.750 +/- .001	4.7473	-0.0027	-0.0017	
	X0.0 +/- .001	0.0029	0.0029	0.0019	
	Y0.0 +/- .001	-0.0009	-0.0009	---	
7	2.500 +.003/-0	2.5018	0.0018	+++	
	X0.0 +/- .001	0.0001	0.0001		
	Y0.0 +/- .001	0.0001	0.0001		
8	2.500 +.003/-0	2.5024	0.0024		
	X0.0 +/- .001	0.0000	0.0000		
	Y0.0 +/- .001	0.0002	0.0002		
9	0.625 +/- .001	0.6276	0.0026	0.0016	
10	2.773 +.005/-0.0	2.7128	-0.0602	-0.0602	

PINHOLDER DET & BTM

TRUE SCALE

[DWG. DETAIL 2-(REV.1)-ITEM 8]

TOLERANCE

$\frac{1}{1000}'' = \frac{1}{10}''$ SCALE

$\frac{1}{100}'' = 1''$ SCALE

SWARZ CONSULTING Inspection Results		Part No. PIN HOLDER DET 8 TOP	J WRIGHT CAMP 2/24/94	
Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance
1	BORE 2.5	ESTABLISH ZERO		
2	.750 +/- .001	.7568	0.0068	0.0058
	X2.375 +/- .001	2.3744	-0.0006	---
	Y0.00 +/- .001	0.0021	0.0021	0.0011
3	.750 +/- .001	0.7562	0.0062	0.0052
	X0.0 +/- .001	0.0003	0.0003	+++
	Y2.375 +/- .001	2.3778	0.0028	0.0018
4	.750 +/- .001	0.7559	0.0059	0.0049
	X-2.375 +/- .001	-2.3730	0.0020	0.0010
	Y0.00 +/- .001	0.0019	0.0019	0.0009
5	.750 +/- .001	0.7568	0.0068	0.0058
	X0.0 +/- .001	0.0012	0.0012	0.0002
	Y-2.375 +/- .001	-2.3724	0.0026	0.0016
6	4.750 +/- .001	4.7488	-0.0012	-0.0002
	X0.0 +/- .001	0.0007	0.0007	+++
	Y0.0 +/- .001	0.0027	0.0027	0.0017
7	2.500 +.003/-0	2.5026	0.0026	+++
	X0.0 +/- .001	-0.0030	-0.0030	-0.0020
	Y0.0 +/- .001	0.0003	0.0003	+++
8	2.500 +.003/-0	2.5001	0.0001	+++
	X0.0 +/- .001	0.0001	0.0001	+++
	Y0.0 +/- .001	0.0000	0.0000	
9	0.625 +/- .001	0.6302	0.0052	0.0042
10	2.773 +.005/-0.0	2.7148	-0.0582	-0.0538

PIN HOLDER DET 8 TOP

TRUE SCALE

[DWG. DETAIL 2 - (REV.1) - ITEM 8]

TOLERANCE

$\frac{1}{1000}'' = \frac{1}{10}'' \text{ SCALE}$

$\frac{1}{100}'' = 1'' \text{ SCALE}$

SWARZ CONSULTING
Inspection Results

Part No.
PIN HOLDER DET 6 AB

J WRIGHT CAMP
2/24/94

Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	.875 +/- .001	0.8751	0.0001	+++	
	X2.375 +/- .001	2.3612	-0.0138	-0.0128	
	Y0.0 +/- .001	0.0183	0.0183	0.0173	
2	.875 +/- .001	0.8746	-0.0004		
	X0.0 +/- .001	-0.0070	-0.0070	-0.0060	
	Y2.375 +/- .001	2.3956	0.0206	0.0196	
3	.875 +/- .001	0.8756	0.0006		
	X-2.375 +/- .001	-2.3842	-0.0092	-0.0082	
	Y0.0 +/- .001	0.0180	0.0180	0.0170	
4	.875 +/- .001	0.8754	0.0004		
	X-.0139 +/- .001	-0.0139	-0.0139	-0.0129	
	Y-2.375 +/- .001	2.3589	0.0161	0.0151	
5	4.75 +/- .001	4.7500	0.0000		
	X0.0 +/- .001	-0.0115	-0.0115	-0.0105	
	Y0.0 +/- .001	0.0184	0.0184	0.0174	

PINHOLDER DETG AB

TRUE SCALE [DWG. DETAIL-2 (REV.1)]

ITEM 6 & 7

SWARZ CONSULTING
Inspection Results

Part No.
PIN HOLDER DET 6 C-D

J WRIGHT CAMP
2/24/94

Item No.	Drawing Specification	Actual Dimension	Dev.	Out of Tolerance	
1	.875 +/- .001	0.8754	0.0004		
	X2.375 +/- .001	2.3613	-0.0137	-0.0127	
	Y0.0 +/- .001	0.0157	0.0157	0.0147	
2	.875 +/- .001	0.8750	0.0000		
	X0.0 +/- .001	-0.008	-0.008	-0.0070	
	Y2.375 +/- .001	2.3929	0.0179	0.0169	
3	.875 +/- .001	0.8759	0.0009		
	X-2.375 +/- .001	2.3879	-0.0129	-0.0119	
	Y0.0 +/- .001	0.0158	0.0158	0.0148	
4	.875 +/- .001	0.8754	0.0004		
	X0.0 +/- .001	-0.0164	-0.0164	-0.0154	
	Y-2.375 +/- .001	-2.3611	0.0139	0.0129	
5	4.750 +/- .001	4.7516	0.0016	0.0006	
	X0.0 +/- .001	-0.0133	-0.0133	-0.0123	
	Y0.0 +/- .001	0.0159	0.0159	0.0149	

PINHOLDER DET G C-D

TRUE SCALE

[DWG. DETAIL-2 (REV.1) - ITEM G#7]

Cleveland Advanced Manufacturing Program

Prospect Park Building 4600 Prospect Avenue
Cleveland, Ohio 44103-4314
216/432-5300 FAX: 361-2900

an Edison Technology Center

March 24, 1994

Mr. Gerhard Schwarz
Schwarz Consulting, Inc.
33020 Lake Road
Avon Lake, Ohio 44012

Dear Gerhard:

The Manufacturing Learning Center is pleased to submit the attached quotation for your consideration.

Upon acceptance, work will begin in the Manufacturing Learning Center after receipt of purchase order.

The total project cost is \$2,664.00 and will be billed to you upon completion.

If you have any questions concerning this quote or need additional information, please feel free to contact me at (216) 987-3204 or (216) 987-3046.

We appreciate the opportunity to assist you in your manufacturing process and look forward to doing business with you in the future.

Sincerely,

Ed Kopinsky
MLC Supervisor

cc: L. Orihill
D. Kresnye
J. Laskowski
D. Rosa
J. Wright

Cleveland Advanced Manufacturing Program
Prospect Park Building 4600 Prospect Avenue
Cleveland, Ohio 44103-4314
216/432-5300 FAX: 361-2900

an Edison Technology Center

2

CCC/MRF MANUFACTURING LEARNING CENTER
2415 Woodland Avenue
Cleveland, Ohio 44115
(216) 987-3090

QUOTATION

Quotation #: 034MLC

Date: 3/24/94

Customer Name & Address: Mr. Gerhard Schwarz
Schwarz Consulting, Inc.
33020 Lake Road
Avon Lake, Ohio 44012
(216) 933-9340

QUANTITY	DESCRIPTION	Price/ each	Total
4	Detail 8 Pinholder	\$ 299	\$1,196.00
4	Detail 9 Shaft, Cam	\$ 367	\$1,468.00
	PROJECT TOTAL		\$2,664.00

Terms:

*Delivery: 4 to 6 weeks ARO

*Not included in this quote are engineering and inspection hours already spent to bring these parts to the point of determination for corrective action.

*Quote valid for 60 days.

Quoted by: _____

Approved by: _____

Date: _____

3/24/94

8. Summary of the Correspondence with the DOE

The following is a summary of the correspondence of SCHWARZ Consulting, Inc. with the U.S. Department of Energy, DOE.

Quarterly Reports since First Quarter of 1992;

January 3, 1994,	Attn.: Jack Aellen;
June 28, 1994,	Attn.: Nita Staub;
January 3, 1995,	Attn.: Terry Levinson;
March 13, 1995,	Attn.: John Windish;
September 20, 1995,	Attn.: Terry Levinson;
January 2, 1996,	Attn.: Victoria Curry;
January 2, 1996,	Attn.: Terry Levinson / Fred Hart;