US 20020162400A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2002/0162400 A1

Xie et al.

(43) Pub. Date: Nov. 7, 2002

(54) MULTIAXIAL HIGH CYCLE FATIGUE TEST SYSTEM

(76) Inventors: **Ming Xie**, Beavercreek, OH (US); **Som R. Soni**, Beavercreek, OH (US); **Charles J. Cross**, Centerville, OH (US); **Gary E. Terborg**, Englewood, OH (US)

Correspondence Address:
Bernard E. Franz
180 Davis Ave.
Enon, OH 45323-1810 (US)

(21) Appl. No.: **10/085,916**

(22) Filed: **Feb. 28, 2002**

Related U.S. Application Data

(60) Provisional application No. 60/273,134, filed on Mar. 5, 2001.

Publication Classification

(51) **Int. Cl.**[7] **G01N 3/32**

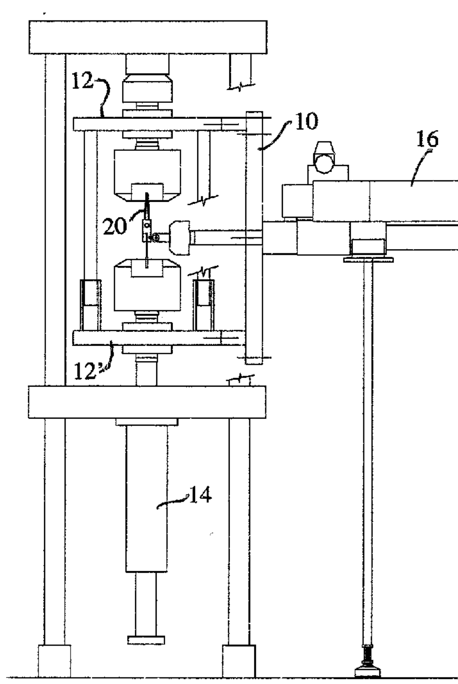
(52) **U.S. Cl.** **73/812**

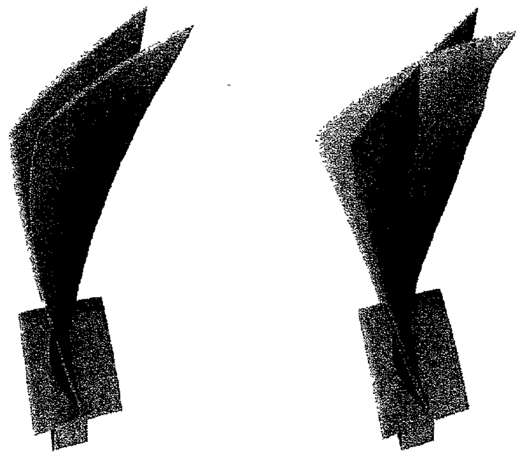
(57) **ABSTRACT**

A multiaxial high cycle fatigue test system for testing bending, torsion, and tension of a test unit, comprises servo-hydraulic components, including a hydraulic service manifold, two small high frequency actuators along a first axis, and one large main actuator along a second axis

The large main actuator is used to apply a radial centrifugal force, and the two small actuators are used to apply vibratory loading; the two small side actuators being offset independently of each other, to enable the machine to apply both bending loads and torque to the test unit.

The test unit is subjected to torsion loading when the traverse actuators move in phase, that is when both actuators move either in or out at the same time. The test unit is subjected to bending loading when the actuators move out-of-phase, that is one actuator moves in when the other moves out or vice-versa.





Bending (First mode) Torsion (Third mode)

Figure 1.1 Bending and torsion of gas turbine fan blade

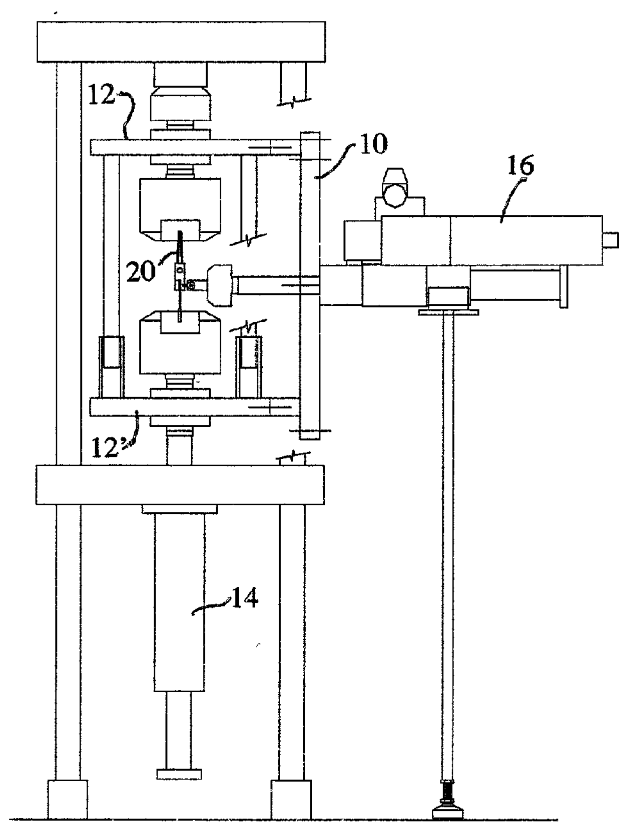


Figure 2.1 Schematic of biaxial loading machine

Figure 2.2 Photograph of biaxial loading machine

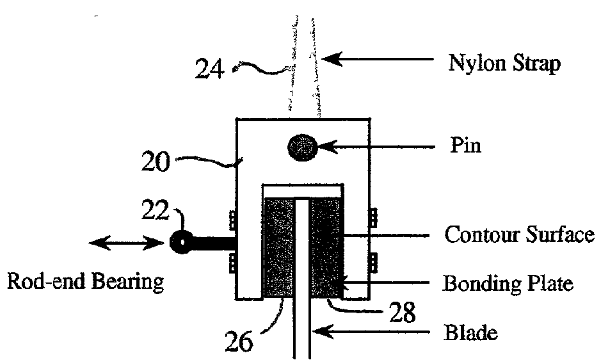


Figure 2.3 Blade gripping system for biaxial machine

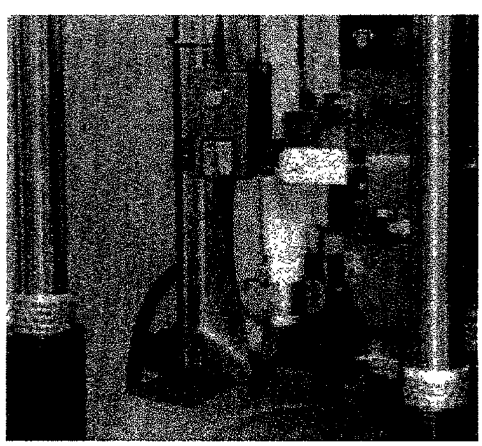


Figure 2.4 Photograph of biaxial loading of GE F110 fan blade

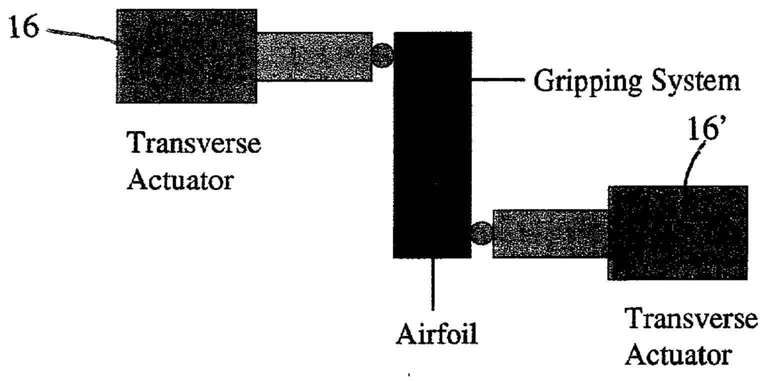


Figure 3.1 Transverse Loading in the Multiaxial Machine

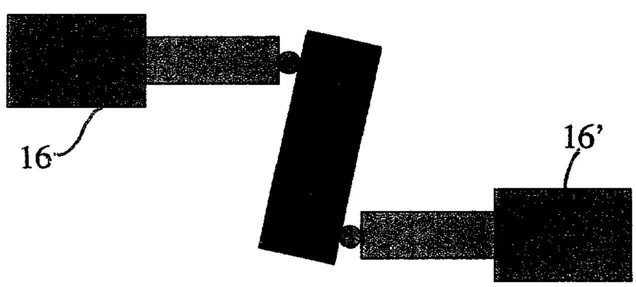


Figure 3.2 Torsion loading

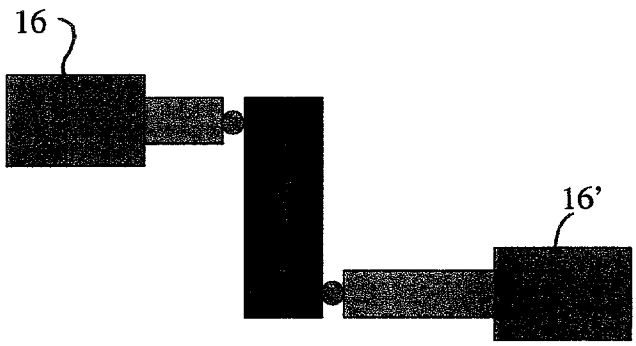


Figure 3.3 Bending loading

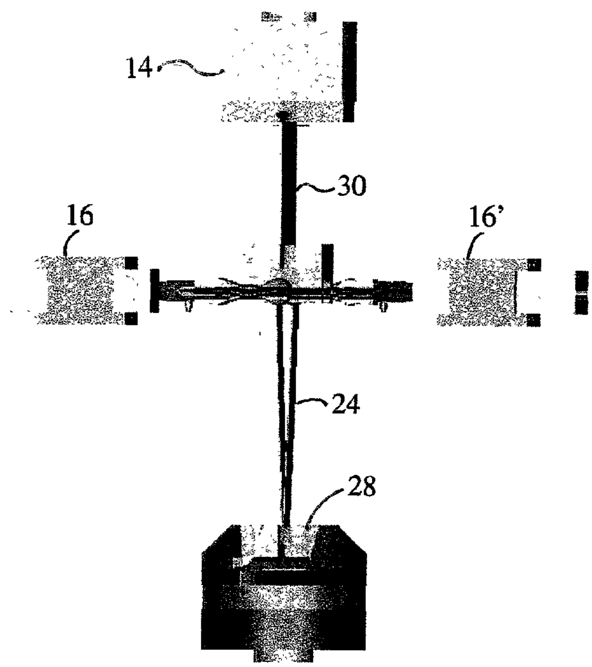


Figure 3.4 Three dimensional model of multiaxial loading mechanism

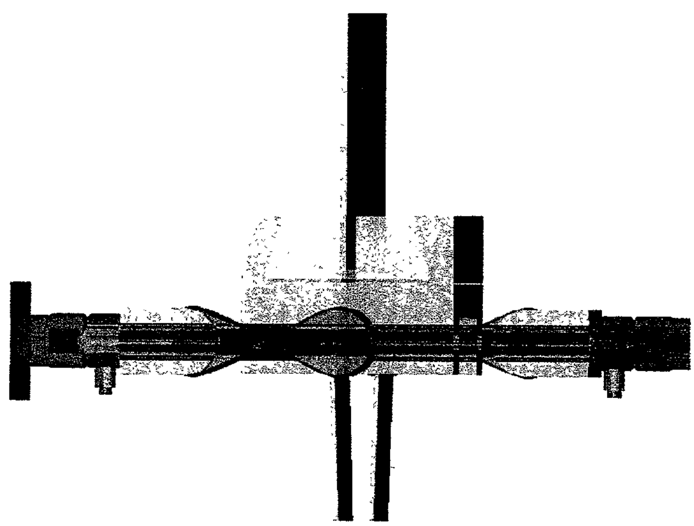


Figure 3.5 Transverse Loading of Blade

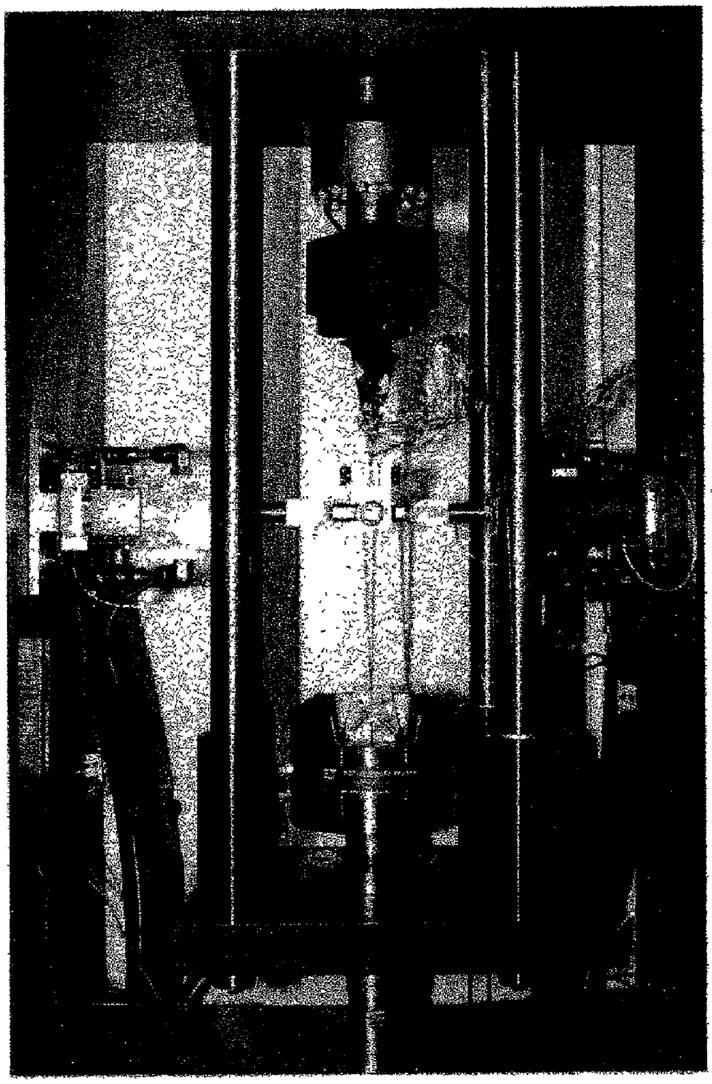


Figure 3.6 Photograph of multiaxial loading setup

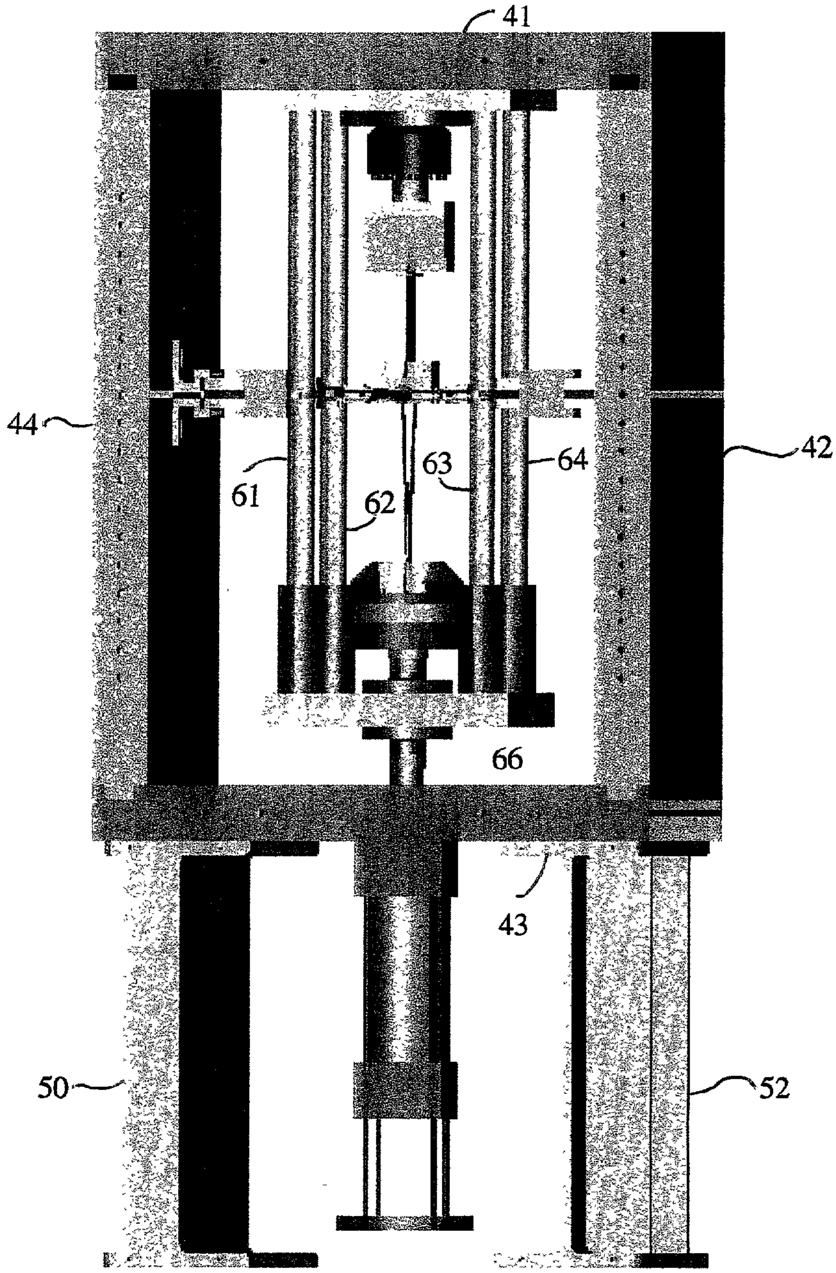


Figure 3.7 Multiaxial Test Frame

Figure 3.8 Photograph of multiaxial machine

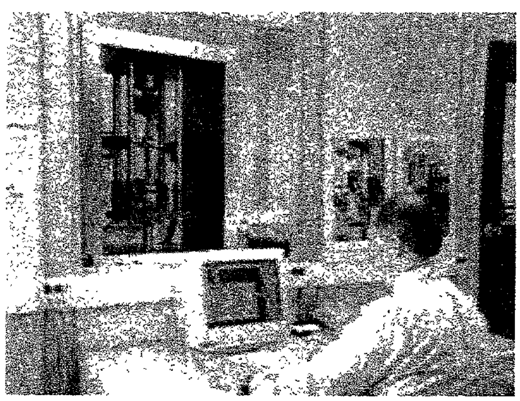


Figure 3.9 Multiaxial machine and operator

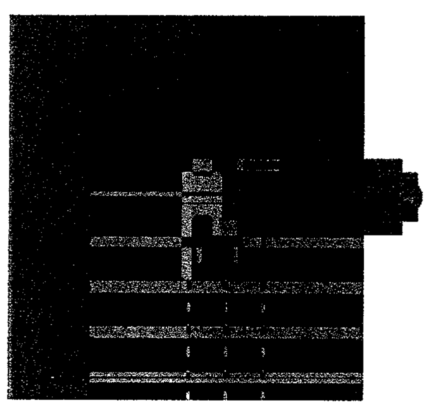


Figure 3.10 Positioning of the transverse actuator

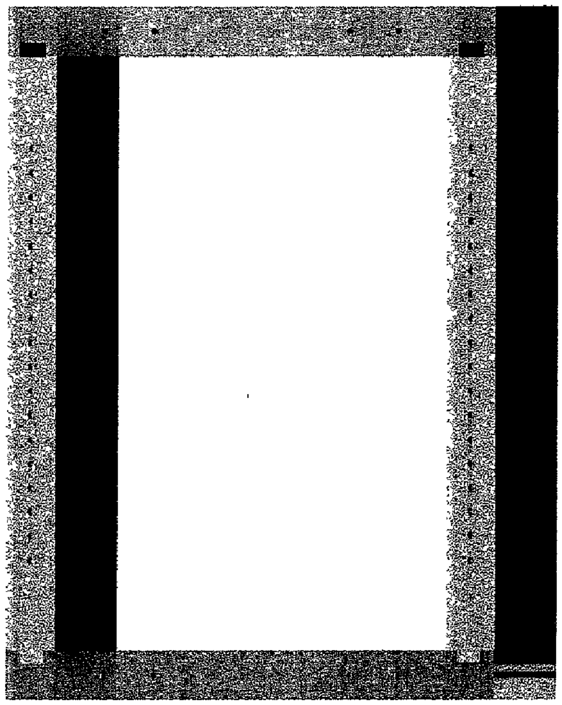


Figure 3.11 Main chamber

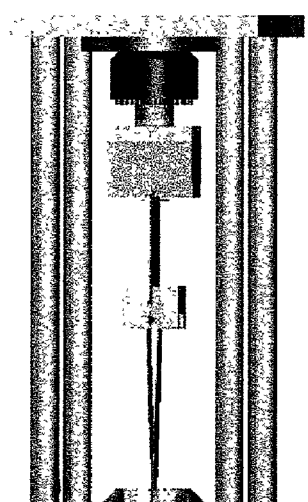


Figure 3.12 Four-post die set

MULTIAXIAL HIGH CYCLE FATIGUE TEST SYSTEM

[0001] Priority is claimed for provisional application serial No. 50/273,134, filed Mar. 5, 2001. The provisional application is hereby incorporated by reference as though fully set forth.

[0002] The U.S. Government has rights in this invention under a development contract with the Air Force, Contract No. F33615-98-2812.

[0003] The invention relates to development of a multiaxial high cycle fatigue test system.

BACKGROUND OF THE INVENTION

[0004] Modern gas turbine engines need to maintain a balance between high performance, affordability, and design robustness. The rotating components of the turbine engine such as fan blades and turbine blades are subjected to high revolutions per minute during operation. As a result, one of the most common modes of failure in engine components is fatigue. This means that to improve the robustness of components, their fatigue behavior would have to be improved.

[0005] Component fatigue behavior can be improved, by improving either the material property or the component geometry or both. Material characteristics are typically studied by testing coupons. The effect of component geometry is lost in coupon tests. Finite element analysis can be used to simulate the actual component behavior to a certain extent. The best method would be to test the actual component by subjecting it to conditions similar to the operating conditions.

[0006] In a gas turbine engine, the fan blades and turbine blades rotate at high revolutions per minute during operation. The blades are subjected to a radial centrifugal force due to this rotation. Gas turbines have alternating stator and rotor blades. The stator blades guide the gas onto the rotor blades. As a rotor blade advances from one stator blade to the next, the gas pressure on the blade decreases and increases again. This results in the application of a cyclic load to the rotor blade. The blade also vibrates at its modal frequency under suitable conditions. These periodic loads result in a vibratory loading on the blade.

The following patents are of interest:

Salberg et al	4,802,365	Feb. 7, 1989
Owen et al	6,023,980	Feb. 15, 2000
Wu et al	4,875,375	Oct. 24, 1989
Meline et al	4,607,531	Aug. 26,1986
von Marinell et al	3,696,512	Oct. 10, 1972
Rao	4,748,854	June 7, 1988
Detert et al	3,603,143	Sept. 7, 1971
Ohya et al	4,869,111	Sept. 26, 1989

[0007] These patents relate to fatigue testing or axial and torsion testing. Sallberg et al have a multi-axial fatigue testing machine.

SUMMARY OF THE INVENTION

[0008] The invention relates to a multiaxial high cycle fatigue test system.

[0009] Vibratory loading causes high cycle fatigue failure in engine blades. To study and improve the fatigue life of gas turbine engine blades, or other test units such as components or material samples, a new test methodology has been proposed. According to this method, the blade or other test unit will be loaded multiaxially during testing, to simulate the actual operating conditions.

[0010] A multiaxial high cycle fatigue test system for testing bending, torsion, and tension of a test unit, comprises servo-hydraulic components, including a hydraulic service manifold, two small high frequency actuators along a first axis, and one large main actuator along a second axis. The large main actuator is used to apply a radial centrifugal force, and the two small actuators are used to apply vibratory loading; the two small side actuators being offset independently of each other, to enable the machine to apply both bending loads and torque to the test unit. The test unit is subjected to torsion loading when the traverse actuators move in phase, that is when both actuators move either in or out at the same time. The test unit is subjected to bending loading when the actuators move out-of-phase, that is one actuator moves in when the other moves out or vice-versa.

[0011] In the embodiment described in the detailed description, the test unit is a turbine blade. In general, the test unit may be any type of complete component, or a material sample, such as a portion of a component.

BRIEF DESCRIPTION OF THE DRAWING

[0012] **FIG. 1.1** shows bending and torsion of a gas turbine blade;

[0013] **FIG. 2.1** is a schematic of a biaxial loading machine;

[0014] **FIG. 2.2** is a photograph of a biaxial loading machine;

[0015] **FIG. 2.3** shows a blade gripping system for a biaxial machine;

[0016] **FIG. 2.4** is a photograph of biaxial loading of a GE F110 fan blade;

[0017] **FIG. 3.1** shows traverse loading in the multiaxial machine;

[0018] **FIG. 3.2** shows torsion loading;

[0019] **FIG. 3.3** shows bending loading;

[0020] **FIG. 3.4** is a three-dimensional model of multiaxial loading mechanism;

[0021] **FIG. 3.5** shows traverse loading of the blade;

[0022] **FIG. 3.6** is a photograph of a multiaxial loading setup;

[0023] **FIG. 3.7** shows a multiaxial test frame;

[0024] **FIG. 3.8** is a photograph of a multiaxial machine;

[0025] **FIG. 3.10** shows positioning of a traverse actuator;

[0026] **FIG. 3.11** shows a main chamber; and

[0027] **FIG. 3.12** shows a four-port die set.

[0028] Appendix A is a User's Manual which contains some computer screen drawings.

[0029] Appendix B comprises several pages of engineering drawings.

DETAILED DESCRIPTION

[0030] 1.0 Introduction

[0031] Modern gas turbine engines need to maintain a balance between high performance, affordability, and design robustness. The rotating components of the turbine engine such as fan blades and turbine blades are subjected to high revolutions per minute during operation. As a result, one of the most common modes of failure in engine components is fatigue. This means that to improve the robustness of components, their fatigue behavior would have to be improved.

[0032] Component fatigue behavior can be improved, by improving either the material property or the component geometry or both. Material characteristics are typically studied by testing coupons. The effect of component geometry is lost in coupon tests. Finite element analysis can be used to simulate the actual component behavior to a certain extent. The best method would be to test the actual component by subjecting it to conditions similar to the operating conditions.

[0033] In a gas turbine engine, the fan blades and turbine blades rotate at high revolutions per minute during operation. The blades are subjected to a radial centrifugal force due to this rotation. Gas turbines have alternating stator and rotor blades. The stator blades guide the gas onto the rotor blades. As a rotor blade advances from one stator blade to the next, the gas pressure on the blade decreases and increases again. This results in the application of a cyclic load to the rotor blade. The blade also vibrates at its modal frequency under suitable conditions. These periodic loads result in a vibratory loading on the blade.

[0034] This vibratory loading causes high cycle fatigue failure in engine blades. To study and improve the fatigue life of gas turbine engine blades, a new test methodology has been proposed. According to this method, the blade will be loaded multiaxially during testing, to simulate the actual operating conditions. A prototype biaxial testing machine was proposed and demonstrated in Phase I of this program. The biaxial machine had two hydraulic actuators perpendicular to each other. This enabled the machine to apply both a radial load to simulate the centrifugal force, and a cyclic transverse load to simulate the vibratory loading. The single transverse actuator facilitated the application of bending loads.

[0035] Vibration of turbine blades include both bending and torsion modes as shown in **FIG. 1.1**. The biaxial machine could not be used to apply torsion loads to the blade, as that required two actuators in the transverse direction. A multiaxial testing machine was proposed, designed and demonstrated in Phase II. The multiaxial machine had three hydraulic actuators, a large actuator along the vertical axis and two small actuators along the horizontal axis. The large actuator was used to apply the radial centrifugal force. The two small horizontal actuators were used to apply the vibratory loading. The two small side actuators can be offset independent of each other. This enabled the machine to apply not only bending loads but also torque to the blade. The application of bending and torsion loads to the blade is explained in detail in Section 3.1.

[0036] 2.0 Prototype Test System with Biaxial Loading Capability

[0037] 2.1 Design of a Biaxial Loading Test Frame

[0038] In Phase I, an existing four-post test frame was modified to test a gas turbine engine fan blade under biaxial loading. A four-post die set was designed and fabricated. It was placed between the top and bottom platforms, and was mounted on the load train. A vertical plate **10** was mounted on the side of the die set **12-12'**, on which a second hydraulic actuator was mounted. **FIG. 2.1** shows the schematic of the biaxial loading machine. **FIG. 2.2** shows a photograph of the completed biaxial loading machine. The vertical actuator **14** was used to apply the steady radial load to simulate the actual centrifugal load on the blade. The horizontal actuator **16** was used to apply the fatigue loading to simulate the actual vibratory load. Both actuators were controlled by an Intelaken DDC4000 controller. The load and time data were collected in a computerized data acquisition system. Labtech Notebook was the data acquisition and analysis software used.

[0039] A gripping system **20** was designed and manufactured to apply the biaxial loading to the blade. A schematic of the gripping system is shown in **FIG. 2.3**. Transverse fatigue loading was applied to the blade through a rod end bearing **22** connection on the grip surface. The rod end bearing was connected to a clevis, which was in turn connected to the piston of the horizontal actuator **16**. The rod-end bearing allows transverse fatigue loading to be applied to the test specimen and at the same time allows small rotation around the gripping. This extra degree of freedom will allow the test specimen to bend under transverse loading.

[0040] A nylon strap **24** was used to connect the fixture to the hydraulic grips. The nylon strap served as the flexible connection that prevented interference between the axial and lateral actuators. The gripping system had two bonding plates **26-28** whose internal contours conformed to the surface of the blade **30**. A photograph of the complete setup is shown in **FIG. 2.4**.

[0041] A broach block was used to hold the turbine blade specimen in place. The broach block resembles a part of the turbine rotor disk. The dovetail of the blade slides into the block, and the blade was tightened against the block by two screws from underneath. The broach block was connected to the vertical actuator directly.

[0042] 3.0 Design of the Multiaxial Loading Test System

[0043] The multiaxial loading test system includes the following subsystems:

[0044] (1) Main test frame **9FIG. 3.7**), including an enclosed chamber with four side walls **41-42-43-44**;

[0045] (2) Main test frame support, including two I-beam pedestals **50-52** reinforced by gussets;

[0046] (3) Auxiliary test frame support, including a four-post die set **61-62-63-64** and other mounting adaptors;

[0047] (4) Servo-hydraulic components, including hydraulic service manifold **66**, two high frequency actuators **16** (1.1 kip, 400 Hz), and one main actuator **14** (11 kip);

[0048] (5) Multiaxial digital control and data acquisition system, including the control console and a computer workstation (FIG. 3.9) (See User's Manual).

[0049] The design features of the above subsystems will be discussed in the following paragraphs.

[0050] 3.1 Concept of Bending and Torsion Loading

[0051] Since vibration of turbine engine blades under service conditions include bending and torsion modes, two actuators have been designed into the test system to simulate the bending and torsional vibration loading. A schematic of the top view of the transverse actuators in relation to the blade is shown in FIG. 3.1.

[0052] The blade is subjected to torsion loading when the transverse actuators move in-phase, that is when both actuators move either in or out at the same time. FIG. 3.2 shows a schematic of the torsion loading. The blade is subjected to bending loading when the actuators move out of phase, that is one actuator moves in when the other moves out or vice-versa. FIG. 3.3 shows a schematic of the bending loading.

[0053] 3.2 Design of the Gripping System

[0054] A new gripping system was designed and manufactured to apply the multiaxial loading to the blade. FIG. 3.4 shows the three-dimensional model of the gripping and loading system developed during the design stage of phase II. The broach block used in phase-I was used after some modifications. The dovetail of the blade slides into the dovetail of the broach block, and the blade is tightened against the block by two screws from underneath. To access these two screws, the broach block has to be removed from the machine every time the blade has to be removed. In phase-I, the broach block was connected to the moving die plate by a threaded rod. So the broach block had to be setup again each time, as its position moved every time it was removed from the machine.

[0055] An adapter was added to the base of the broach block in phase-II. The adapter was connected to the stationary die plate by a threaded rod. The broach block was located on the adapter plate by two dowel pins, and it was attached to the adapter plate by four bolts. This facilitated the easy assembly and removal of the broach block and the blade for each test. The dowel pins ensured that the broach block is returned to the same position as before it was removed from the machine. This eliminates the need for setting up the broach block between tests on same or similar blades.

[0056] The strap 24 is gripped by a hydraulic wedge grip 28. In phase-I, the hydraulic grip was mounted on the top (fixed) die plate, while the broach block and specimen were mounted on the bottom (movable) die plate attached to the vertical actuator 14. As a result, the position of the specimen relative to the transverse actuator changed whenever the vertical actuator moved and whenever the hydraulic power was switched off. In the new multiaxial test frame, the hydraulic grip is mounted on the bottom (movable) die plate attached to the vertical actuator. The broach block and the specimen are mounted on the top (fixed) die plate. This ensures that the relative distance between the specimen and the transverse actuators remains undisturbed by the movements of the vertical actuator. This also enables quick change over from one test to another on same or similar blades, by eliminating changes in the critical locating dimensions.

[0057] A load cell of 2000 lb capacity supplied by Sensotec is mounted on the piston rod of each transverse actuator using an adapter. A clevis is attached to the load cell. The clevis is connected to the grip pin using two rod end bearings. The grip pin extends from one end of the grip to the other end. When the piston rod of a lateral actuator moves forward, it pushes one end of the grip pin forward via the clevis and the rod end bearings. This results in the application of a force to the specimen in the direction of the actuator movement. The rod end bearings and the clevis joints allow movement of the grip in the vertical direction to a certain extent. A three-dimensional model of the transverse loading mechanism is shown in FIG. 3.5. A photograph of the GE F110 gas turbine engine fan blade subjected to multiaxial loading using the gripping system is shown in FIG. 3.6.

[0058] 3.3 Hydraulic Components and Control System

[0059] The hydraulic control system and the actuators were procured from Instron Schenk Testing Systems. Labtronic 8800 multi-axis digital control console manufactured by Instron is used to control all the three actuators. It monitors the load and displacement conditions while performing high speed data acquisition. Labtronic 8800 has multi-station capability. The Labtronic 8800 control console is connected to a personal computer running Windows NT. A software called RS Console is used for interacting with the Labtronic 8800 control console. RS Console can be used for set up, waveform generation and setting of limits. It uses a wizard to provide simple easy to use instructions for complex operations. The software also includes multiple live displays for digital readout of data. RS Console has function generators that can be interlocked with phase control. This enables the maintenance of phase relations between the actuators during cyclic loading.

[0060] The two lateral actuators are of type PLF7D supplied by Instron. Each actuator has a capacity of 1,100 lb (5.2 kN) and 20 mm stroke. These actuators can apply high frequency loading up to 400 Hz. Standard fatigue rated actuators using high pressure rod seals experience a banding problem resulting in early failure. When the dynamic stroke is too small to carry fresh oil under the seals, the oil film breaks down and results in damage to the rod. The PLF7D servo hydraulic actuators are designed, built and optimized for high frequency operation. Hydrostatic bearings and laminar high pressure seals allow sustained high frequency, short stroke operation. The actuator does not have any elastomer seals in contact with the piston rod during operation. The single rod seal that prevents external leakage when turned off is retracted from the rod when operating. A suction pump is used to scavenge the leakage oil during operation.

[0061] The vertical actuator is a labyrinth bearing pedestal base actuator supplied by Instron. The actuator has a dynamic force rating of +/−11,000 lb (50 kN) and +/−50 mm stroke. The rod diameter is 63.5 mm and the actuator stall force is 63 kN. The load in the vertical direction is measured by a dynamic load cell of 11,000 lb (50 kN) capacity.

[0062] All three actuators are connected to servo valves. The servo valves are connected to a hydraulic service manifold (HSM). The hydraulic service manifold is in turn connected to the hydraulic power supply. Accumulators are provided in the hydraulic service manifold to enable high frequency operation of the actuators.

[0063] The procedure for operating the test frame using the RS Console software and the Labtronic 8800 controller are described elaborately in Appendix A.

[0064] 3.4 Design of the Multiaxial Test Frame

[0065] The major structural components of the multiaxial test frame are a main chamber with four side walls, two I-beam pedestals and a four-post die set. **FIG. 3.7** shows a three-dimensional model of the multiaxial test frame.

[0066] A photograph of the complete multiaxial test frame is shown in **FIG. 3.8**. The test frame and the hydraulic service manifold are located inside an enclosed test chamber as shown in **FIG. 3.9**. The control system and the personal computer that acts as the interface with the user are located outside the chamber. This isolation of the test frame helps to reduce the noise pollution of the surroundings. The I-beam pedestals of the machine are bolted to a metallic test bed using T-bolts. This prevents the machine from moving due to vibrations during high frequency tests. The I-beams are separated from the test bed by neoprene pads. The neoprene pads reduce the transfer of vibrations from the test frame to the test bed.

[0067] The side frame walls of the test frame have three rows of threaded holes. The actuator fixtures are bolted to the side frame walls using these holes. This is shown in **FIG. 3.10**. The rows of holes allow the actuator fixtures to be moved and positioned both in the vertical and horizontal directions. This enables the positioning of the lateral actuators at different points with respect to the specimen. The base of the lateral actuator slides inside a slot in the actuator fixture and the actuator is bolted to the fixture. This allows the actuator to be moved along the slot to a certain extent for quick adjustments. The actuator fixture has slots that are used to bolt it to the side frame wall. These slots allow the fixture to be moved in the vertical direction to a certain extent for quick adjustments.

[0068] The main chamber of the multiaxial test frame consists of four frame walls that are 4 inch thick. The construction of the main chamber is shown in **FIG. 3.11**. The top and the bottom frame walls have machined grooves. The side frame walls have matching machined projections that rest in these grooves. This reduces the movement of the side frame walls due to the forces from the transverse actuators. This also reduces the transfer of the transverse forces to the bolts holding the walls together. A row of threaded holes is provided on the front and back sides of the frame walls to facilitate easy attachment of ancillary equipment such as measuring devices and cameras.

[0069] A four-post die set is used in the vertical load train. The four-post die set is used to minimize the effects of the lateral loading on the piston rod of the vertical actuator. The top plate of the die set is bolted to the top frame wall. The load cell that measures the load in the vertical axis is bolted to the top plate. The broach block is attached to the broach block adapter plate, which in turn is attached to the load cell. The hydraulic grip used to grip the strap is mounted to the bottom die plate using a threaded rod. The bottom die plate is attached to the piston rod of the vertical actuator. When the piston rod of the vertical actuator is moved downwards, the strap is pulled resulting in a vertical load on the specimen. The four-post die set is shown in **FIG. 3.12**.

[0070] The actual dimensions of the manufactured parts and the materials used to manufacture them are shown in the detailed drawings attached as Appendix B.

APPENDIX A

Multiaxial HCF Testing System User's Manual

AdTech

SYSTEMS RESEARCH, INC.

MULTI-AXIAL FATIGUE TEST FRAME OPERATIONS MANUAL

TABLE of CONTENTS

1	**SYSTEM OVERVIEW**	1
	1.1 Hydraulic System	1
	1.2 Control System	1
	1.3 Mechanical System	2
2	**SYSTEM PREP AND START-UP**	3
	2.1 Hydraulic System Start-up	3
	2.2 Electronic Control System Start-up	3
	2.2.1 Labtronic 8800	3
	2.2.2 Test Toolbar / RS Console	4
	2.2.3 Hydraulic Flow Initialization	4
	2.3 RS Console-Test Group 1	5
3	**SYSTEM OPERATION**	6
	3.1 Load Cell Calibration	6
	3.1.1 Load Cell Calibration	6
	3.2 Component Attachment	7
	3.2.1 Positioning Actuators	7
	3.2.2 Attaching Actuators to the Component	8
	3.3 Cyclic Waveform Generator	9
	3.3.1 Cyclic Waveform Generator Overview	9
	3.3.2 Cyclic Waveform Generator Operation	10
4	**SYSTEM SHUTDOWN**	12
	4.1 Control System Unload	12
	4.2 Hydraulics Shutdown	12

1 SYSTEM OVERVIEW

1.1 HYDRAULIC SYSTEM:

The Hydraulic System is comprised of the following components:

- MTS 506 Hydraulic Compressor located in Bldg. #252 Room 25227. The compressor operates at 3000 psi. and has a flow rate of 75 gpm.

- Instron Servo Hydraulic Actuators: Model: PLF7D
  Load rating: 5.2 kN; Stroke: 20 mm.
  Identification: **"Axis 1"** is located on the Left Test Frame Wall mounted in a horizontal position.

- Instron Servo Hydraulic Actuators: Model: PLF7D
  Load rating: 5.2 kN; Stroke: 20 mm.
  Identification: **"Axis 2"** is located on the Right Test Frame Wall mounted in a horizontal position.

- Instron Servo Hydraulic Actuator: Model: A1287-3010;
  Load rating: 50 kN; Stroke: 150 mm.
  Identification: **"Axis 3"** is located on the Lower Test Frame Wall mounted in a vertical position.

- 1 LABTRONIC #8800 Hydraulic Manifold Controller.

1.2 ELECTRONIC CONTROL SYSTEM:

The Control System is comprised of the following components:

- Instron RS Console Control Software.

- Instron RS PLUS 32 Data Acquisition Software.

- Instron Remote Jog Handset.

- 400 MHz CPU, 64 MB RAM, Dell Computer and monitor.

1.3 MECHANICAL SYSTEM:

The Mechanical System is comprised of the following components:

- 4 - 4" Thick Cold Rolled Steel nickel-plated panels
- 4 Post Danly Die Set
- Model 647 Hydraulic Wedge Grip
- Mounted on 2 Steel Gusseted "I" Beams

2 SYSTEM PREP AND START-UP

2.1 HYDRAULIC SYSTEM START-UP

Initiate start-up of MTS 506 Hydraulic Compressor located in Bldg. #252 Room 25227. Start-up instructions are shown below and are located on the front of the control panel to the compressor.

MTS HYDRAULIC PUMP START-UP

1. Check that chilled water is on. (South side of Bldg. #252 top white tank temp. of 60°F or lower).

2. Check the hydraulic fluid level (in pump room, fluid gage is located on the right side of pump).

3. Check that power is on at breaker (in pump room breaker SS-H1).

4. Make sure that all of the Red Stop and Emergency buttons are out.

5. Turn on hydraulic pump:
   a. Spchg. pump (auto)
   b. Source (local)
   c. Main pump
   d. Rotate switch to start
   e. Back to low for two minutes
   f. Rotate switch to high

2.2 ELECTRONIC CONTROL SYSTEM START-UP

2.2.1 LABTRONIC 8800

Part of the function of the Labtronic 8800 is the electronic control for the flow of hydraulic fluid to the three Hydraulic Actuators.

Hydraulic flow is controlled at four different levels; Off, Pilot, Low, and High.

The system has a Main Unit Power toggle switch located on the back and top of the unit. Additionally there is an on and off "Hydraulic Main" switch which is located on the front and left of the unit. Once the back Main Unit Power switch has been initiated, the unit should be allowed a couple minutes to warm-up prior to establishing contact with the RS Console software.

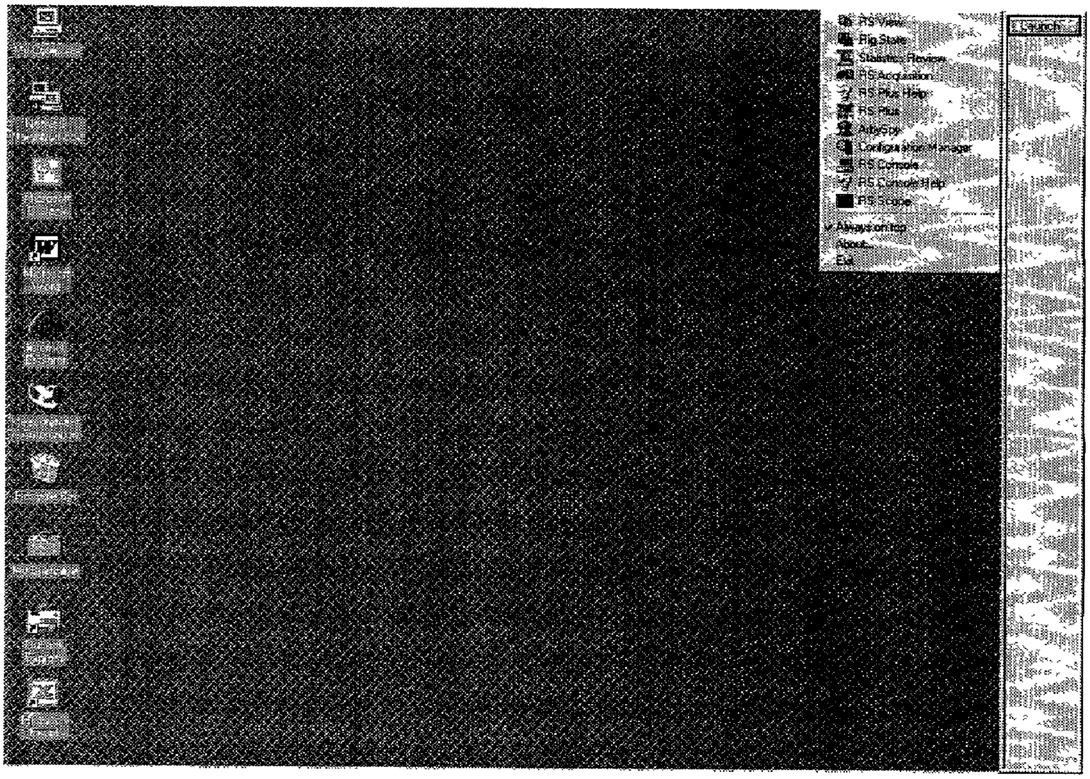

RS View
Rig State
RS Plus Help
RS Plus
RS Console
RS Console Help
RS Scope
Always on top

Figure 2-1

Scroll down and select the RS Console option, within this application you can set-up and control all of the functions of the systems actuators.

2.3 RS CONSOLE - TEST GROUP 1

Test Group 1 is the home for all transducer readouts and control system of the three hydraulic actuators. When initially opened, the Test Group 1 has 14 control tabs. Their descriptions are as follows from left to right and top to bottom:

1. STOP: Stops all active waveforms.

2. SETPOINT: Controls movement of the actuators either in position or load control to a given position.

3. CYCLIC WAVEFORM: Allows the user to setup the operation of the actuators in a detailed format functioning together as a system or to operate each actuator individually. (See section 5.2 Overview of Instrons Labtronic 8800 Operating Instructions).

4. RAMP GENERATOR: Allows the user the option of operating the system with various ramp shapes. (See section 5.2 Overview of Instrons Labtronic 8800 Operating Instructions).

5. TRANSDUCER READOUT: Displays a readout of the stroke position, and load output. Along with the load and stroke readouts are the options to read frequency and time. Entering the properties of each readout allows the user further control of the readout parameters. This is done by placing the cursor over one of the readout windows and hitting the right mouse button. The Transducer Readout window can also be "docked" as shown in Figure 3-1.

6. AXIS TABS: Each actuator has an Axis Tab that contains a variety of control options for that given actuator. Clicking on this tab opens a Controller Properties window displaying those control options.

7. DISPLACEMENT TABS: Next to the Axis Tabs are the Displacement or Stroke Tabs that allow defined control over the stroke. Clicking on this tab opens the Sensor Properties window displaying various control options, such as Calibration and Limit Settings.

8. LOAD TABS: Next to the Displacement Tabs are the Load Tabs that allow defined control over the load. Clicking on this tab opens the Sensor Properties window displaying various control options, such as Calibration and Limit Settings.

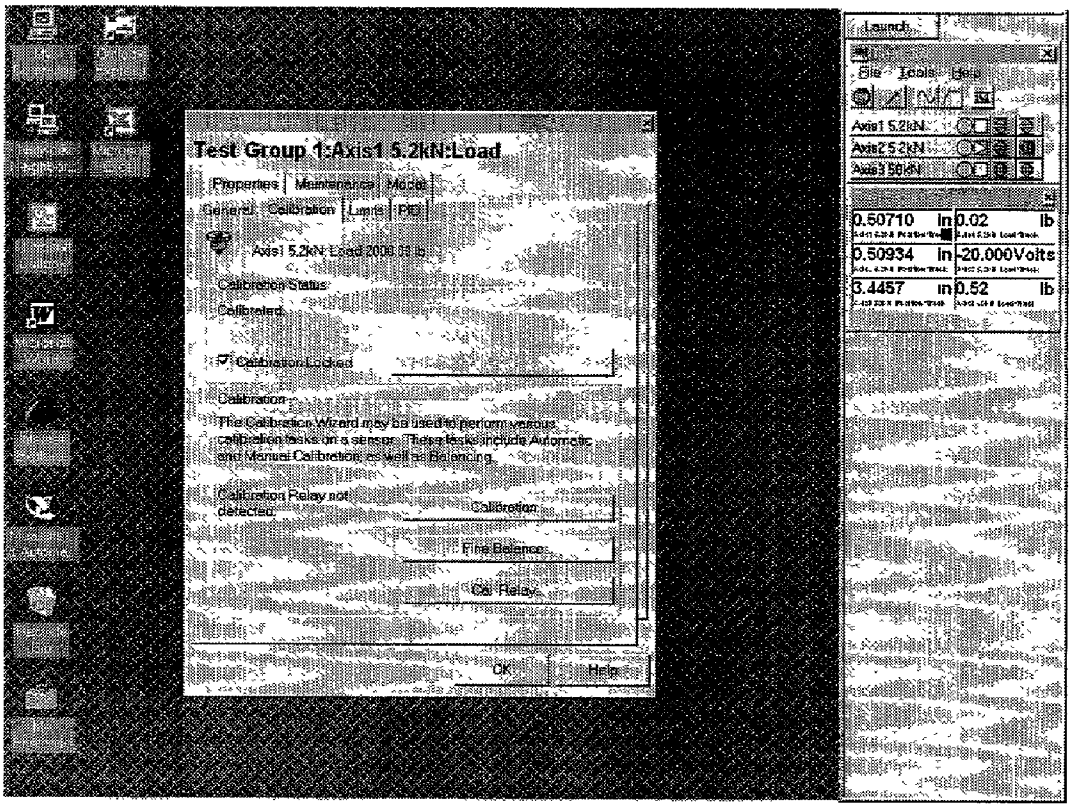

Launch
File Tools Help
Axis1 5.2kN
Axis2 5.2kN
Axis3 50kN
0.50710 in
0.02 lb
0.50934 in
-20.000Volts
3.4457 in
0.52 lb
Test Group 1:Axis1 5.2kN:Load
Properties
Maintenance
Model
General
Calibration
Limits
PID
Calibration Status
Calibrated.
Calibration Locked
Calibration
The Calibration Wizard may be used to perform various calibration tasks on a sensor. These tasks include Automatic and Manual Calibration, as well as Balancing.
Calibration Relay not detected.
Calibration...
Fine Balance...
Cal Relay...
OK
Help

Figure 3-1

2. Select the load cell control button.

3. Next select the tab marked "Calibration".

4. Select the button marked "Calibration".

5. Confirm that the "Auto and Manual" calibration option is selected. Then hit the "Next" button.

6. Confirm that the Sensor details are correct and select the "Next" button.

7. Confirm that the Sensor Span Point is correct and select the "Next" button.

8. Confirm that either the "Auto Calibration" or the "Course Balance" options are selected along with the "Open" option within the "Cal. Relay" section.

9. Select the "Start" button to begin the calibration. On Axis 3 when selecting the start button, the software will automatically advance you through steps 9-11. For Axis 1 and 2 you will need to input steps 9-11 manually.

10. Within the "Status" dialog box you will be prompted for the next step, e.g. (Course balanced, waiting for Span.)

11. Change Cal. Relay to the "close" position and hit the Start button.

12. With Span finished and waiting for the Fine Balance, change Cal. Relay to the "open" position and hit the Start button to finish the calibration procedure.

Upon completion of the calibration you will be given an opportunity to save the calibration data to a file that can be recalled at a later date or you can select "Finish". Finally select "OK" to close out of the Sensor Properties window.

3.2 COMPONENT ATTACHMENT

3.2.1 POSITIONING ACTUATORS

Select the Setpoint control button located within Test Group 1 (see Figure 3-1).

1. Select the Group Setpoint control tab. This allows complete control of all actuators, including the ramp time, mode of control (stroke or load) and your desired target position for all actuators.

2. Select "Position" control for all Axis 1 thru 3, located beneath the "Mode" column.

3. Located at the test frame are three Remote Jogging Handsets, one for each axis (actuator). Each Handset has the capacity to extend or retract each actuator at either a slow or faster rate depending upon which buttons are pushed.

4. Insure that all mechanical connections are tightened as needed.

5. Using the Handsets, extend each actuators ram (taking care on proper alignment of gripping devices and the component) so that all Axis 1 and 2 couplers are aligned with the gripping device located on the component. DO NOT MAKE THE FINAL ATTACHMENT TO THE COMPONENT.

6. Using the Handset on Axis 3, extend the ram to the desired position and hold.

7. A red emergency stop button is located to the lower right side of the test frame, which will deactivate all of the hydraulics to all actuators if needed.

3.2.2 ATTACHING ACTUATORS TO THE COMPONENT

1. A strap is used to apply the tension load on Axis 3. Loop the strap over the components grip and while applying an even pull on the strap, slide it into the hydraulic grip wedges and initiate the grip on Axis 3. Adjust the wedge gripping pressure to sufficiently grip the strap. There should be no load on this axis at this time.

2. At the Setpoint control within Test Group 1, change Axis 3 to Load control. Establish and activate the "Upper Sensor Limit" settings for Axis 3 (this can be found by clicking on Axis 3's load cell button, within Test Group 1).

3. Input your target tension load on Axis 3 and hit enter ("Enter" must be hit after entering any numerical target command). Adjust your Ramp time accordingly (approx. 20 seconds and hit enter).

4. Select the start button to initiate Axis 3's tension load. All actuator movement can be stopped by hitting the "Stop" button located within Test Group 1 or by pushing the Red Emergency Stop knob on the Labtronic 8800 (this will dismantle all hydraulic flow to all actuators). The operator should be familiar with both before initiating any actuator movement.

5. With full tension load applied to Axis 3, carefully use the "jogging handsets" to bring the couplers located on Axis 1 and 2 into alignment with the grips on the component and attach.

6. Axis 1 and 2 will remain in stroke (position) control for the test and at this time the operator should set their respective "Upper and Lower Sensor Limits" (these can be found by clicking on their Position button (square button with the upper and lower arrow heads), within Test Group 1).

3.3 CYCLIC WAVEFORM GENERATOR

3.3.1 CYCLIC WAVEFORM GENERATOR OVERVIEW

The Cyclic Waveform Generator is capable of controlling each axis individually, or it is capable of controlling two or more axis as a group with all axis beginning and ending as a unit. The Cyclic Waveform Generator can be located within Test Group 1, and it can be accessed by clicking the square button with the Sine wave symbol.

The waveform generator can be started and stopped by selecting three of the five large buttons located at the top of the Waveform Generator window. They are described by the following (see Figure 3-2):

1. Start: Starts all waveform action on all axis that have the box labeled "Include Axis in Master Waveform Control", checked. Upon selecting this button the operator will receive a confirmation/warning showing exactly what actuators will be started and will do so when "OK" is selected. The actuators will then ramp up to the parameters set forth at a rate specified within "Attack:"

2. Hold: Stops all waveform action on all axis that have the box labeled "Include Axis in Master Waveform Control", checked. All axis will be stopped at the point where they are located within their respective cycle when the button is hit.

3. Reset: Stops all waveform action on all axis that have the box labeled "Include Axis in Master Waveform Control", checked. All axis will be stopped within the time frame specified in "Decay" and all axis will return to their respective starting point when the cycle begins.

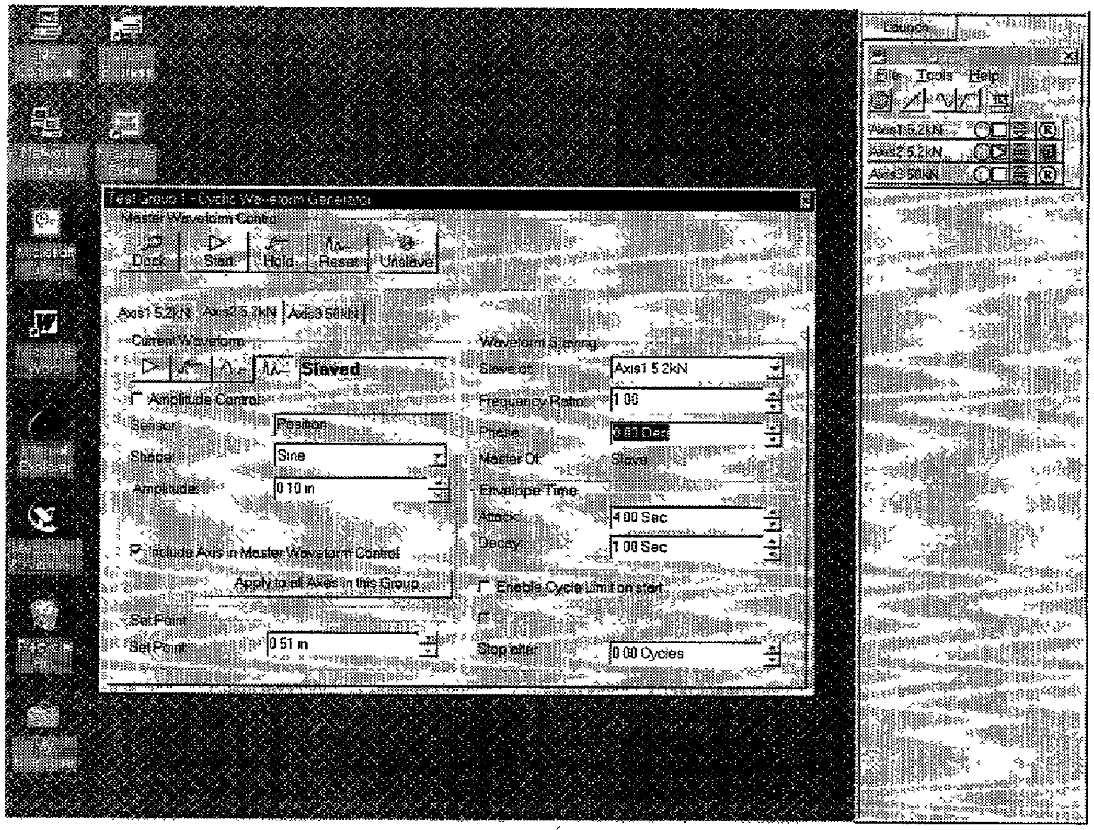

Launch
File Tools Help
Axis1 5.2kN
Axis2 5.2kN
Axis3 50kN
Test Group 1 - Cyclic Waveform Generator
Master Waveform Control
Dock
Start
Hold
Reset
Unslave
Axis1 5.2kN
Axis2 5.2kN
Axis3 50kN
Current Waveform
Slaved
Amplitude Control
Sensor
Position
Shape
Sine
Amplitude
0 10 in
Include Axis in Master Waveform Control
Apply to all Axes in this Group
Set Point
Set Point
0 51 in
Waveform Slaving
Slave of
Axis1 5 2kN
Frequency Ratio
1 00
Phase
Master Of
Slave
Envelope Time
Attack
4 00 Sec
Decay
1 00 Sec
Enable Cycle Limit on start
Stop after
0 00 Cycles

Figure 3-2

6. Select the Axis 3 tab and confirm that the box labeled "Include Axis in Master Waveform Control" is NOT CHECKED. This axis will not have a cyclic waveform generated through it. All other parameters found within this tab can be left as they are.

7. As described above in section 3.4.1, selecting the large start button will start the Cyclic Waveform Generator.

8. To stop a waveform, the operator has two options: either select the large "Hold" or "Reset" buttons located at the top of the waveform generator's screen. Their individual functions are described in Section 3.3.1.

4 SYSTEM SHUTDOWN

4.1 CONTROL SYSTEM UNLOAD

1. Upon completion of a test or at anytime the operator wants to dismantle the test setup, the waveform generation should be stopped by selecting the "Reset" button. This allows the actuators on Axis 1 and 2 to return to a unloaded position. Axis 3 however will remain loaded since it was not included in the waveform function.

2. Before proceeding check for any component or test fixture failure as this may dictate how the test frame should be unloaded.

3. Remove the couplings that are gripping the component on Axis 1 and 2. If needed, Axis 1 and 2 can be retracted using the Jogging Handsets. However remember to disable the Stroke Limits that may have been set on Axis 1 and 2 first.

4. If no failure is noted select the Load Cell button for Axis 3 and go to the Limit tab and uncheck the enabled button for the "Lower Sensor Limit". The "Upper Sensor Limit" should be left enabled for safety.

5. Select the Setpoint Control button and input a new lower target load for Axis 3 of around 20 lbs. tension and hit "Enter".

6. Select a new Ramp time of approximately 10 sec. and hit "Enter". Select the Start button, and the load on Axis 3 should reduce to the target load over the 10 sec. time period. The system can be stopped by selecting the small square stop button within Test Group 1 or by hitting the Emergency Stop button on the Labtronic 8800.

7. At the test frame, release the hydraulic grip pressure that is holding the strap. By allowing 20 lbs. of tension as explained in Step 2 this should allow a slow descent of the ram on Axis 3.

4.2 HYDRAULICS SHUTDOWN

1. Prior to deactivating the hydraulics, an examination of the test frame is important to ensure that there is nothing to interfere with the possible movement (retraction) of the three actuators.

2. All hydraulic flow to the actuators is controlled through the Labtronic 8800 and can be stopped by selecting each actuators' Off button located beneath the "Hydraulics 1, 2, and 3 control panel.

3. Close all of the RS console software windows and completely exit off of the computer.

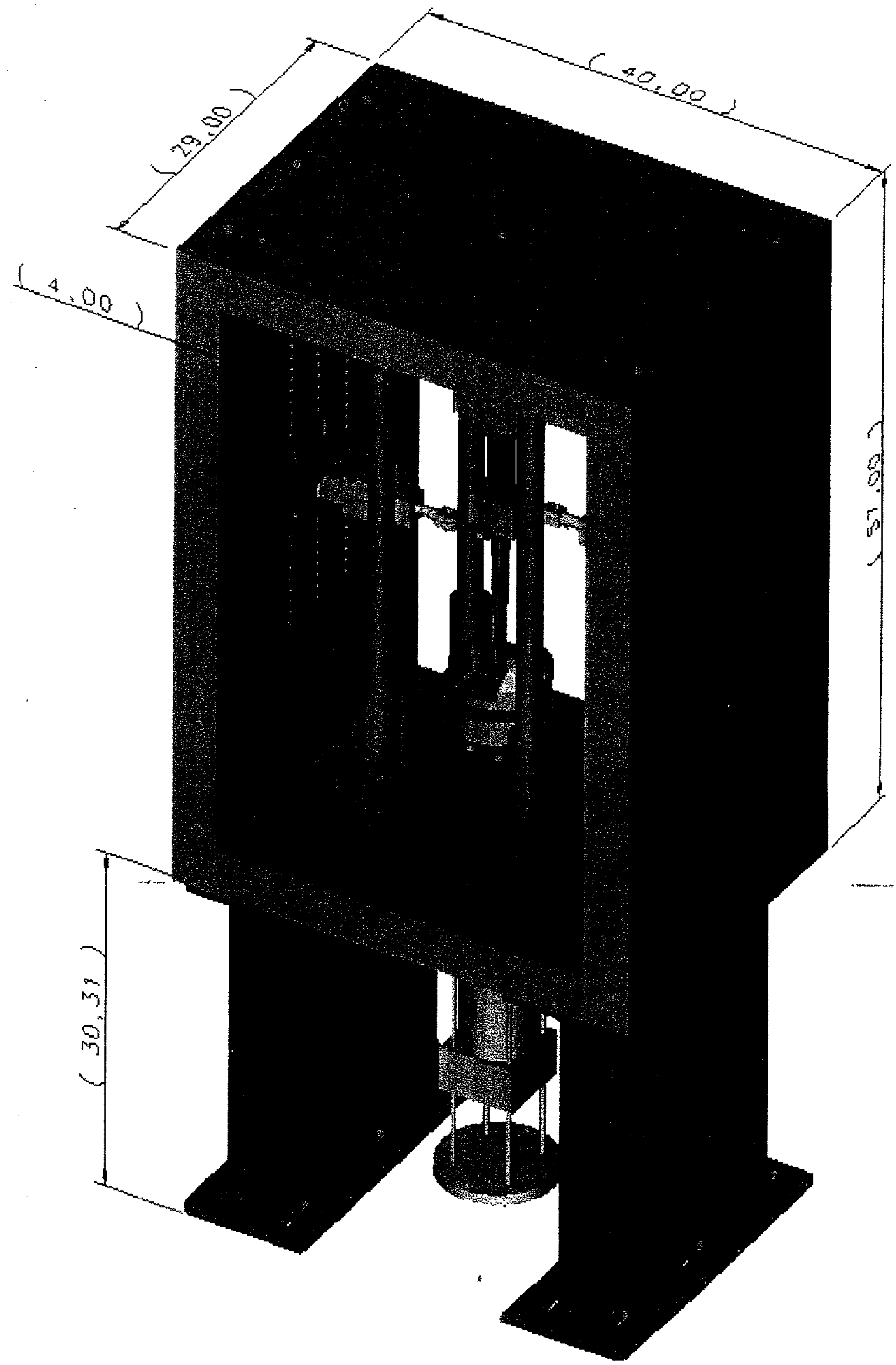
4. Deactivate the Labtronic 8800 by reversing the procedures set forth in Section 2.2.1.

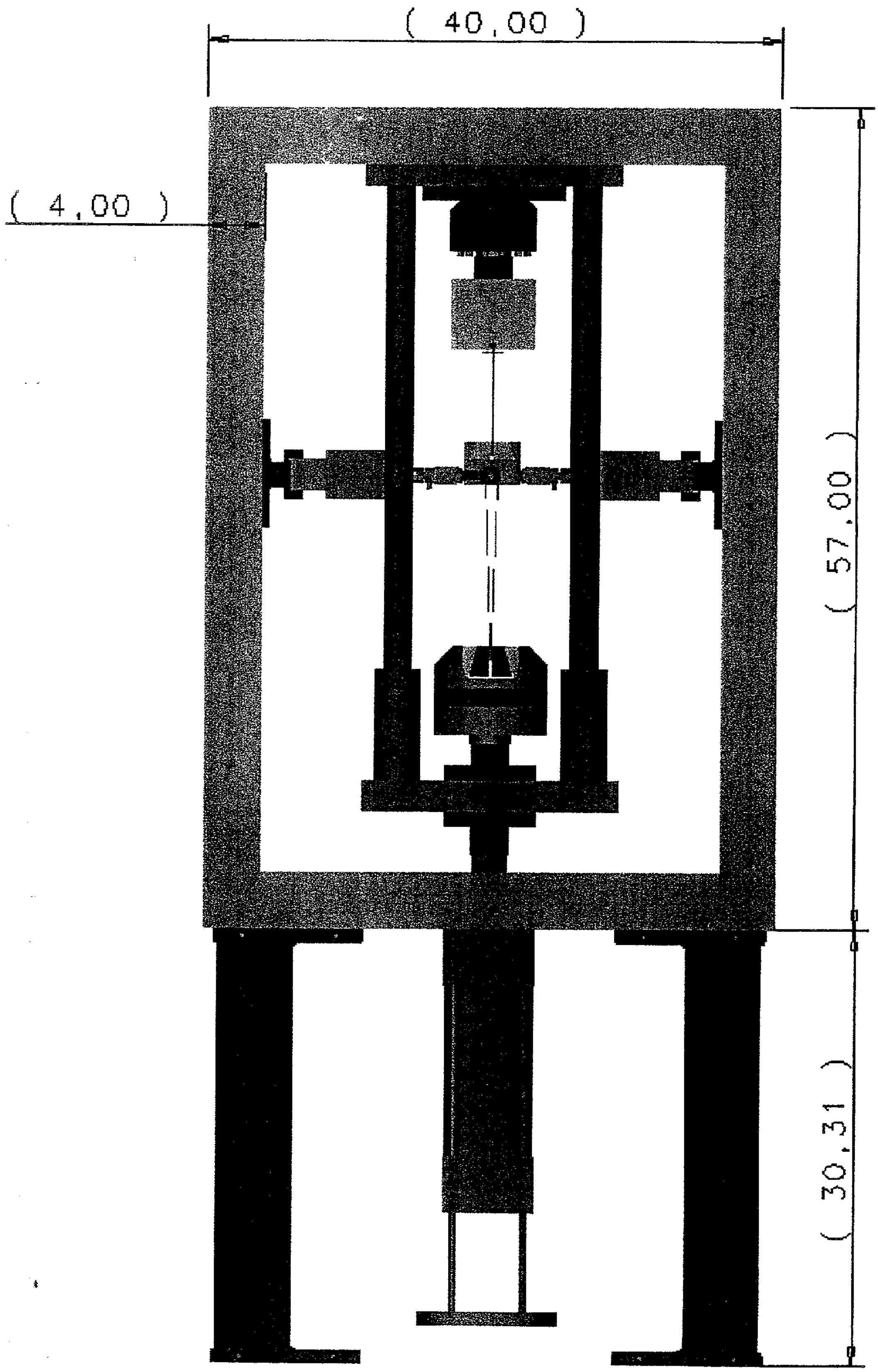
5. Shutting down the main hydraulic compressor can be done at the compressor itself by turning the "Main Pump" switch to low and hitting the large Stop button.

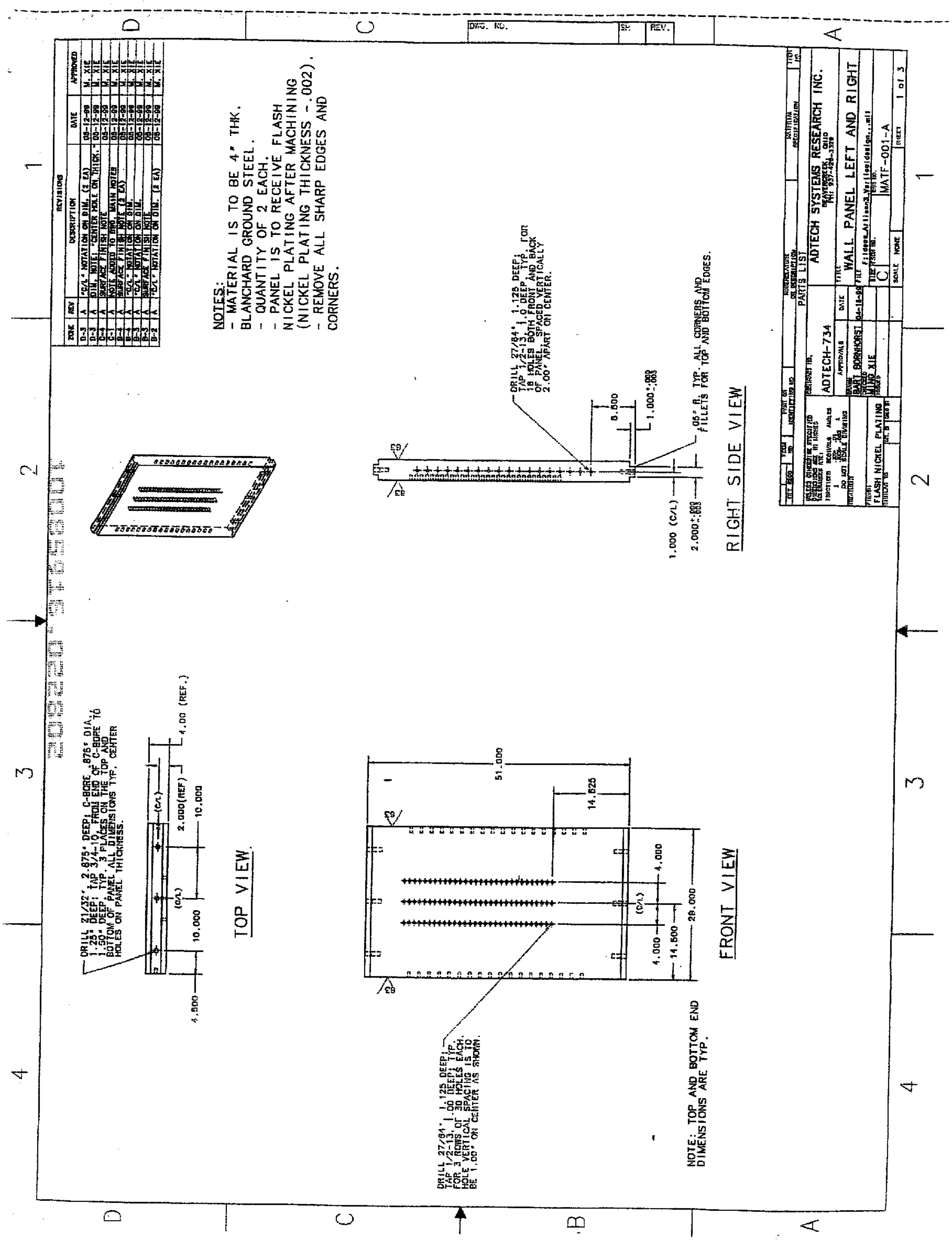
6. Shutting down the main hydraulic compressor can also be done at one of the Emergency Shutoff buttons that are located at the exit doors above the 6' level in rooms 25220, 25222, 25223 and 25224. The operator should note their locations prior to starting the hydraulic compressor.

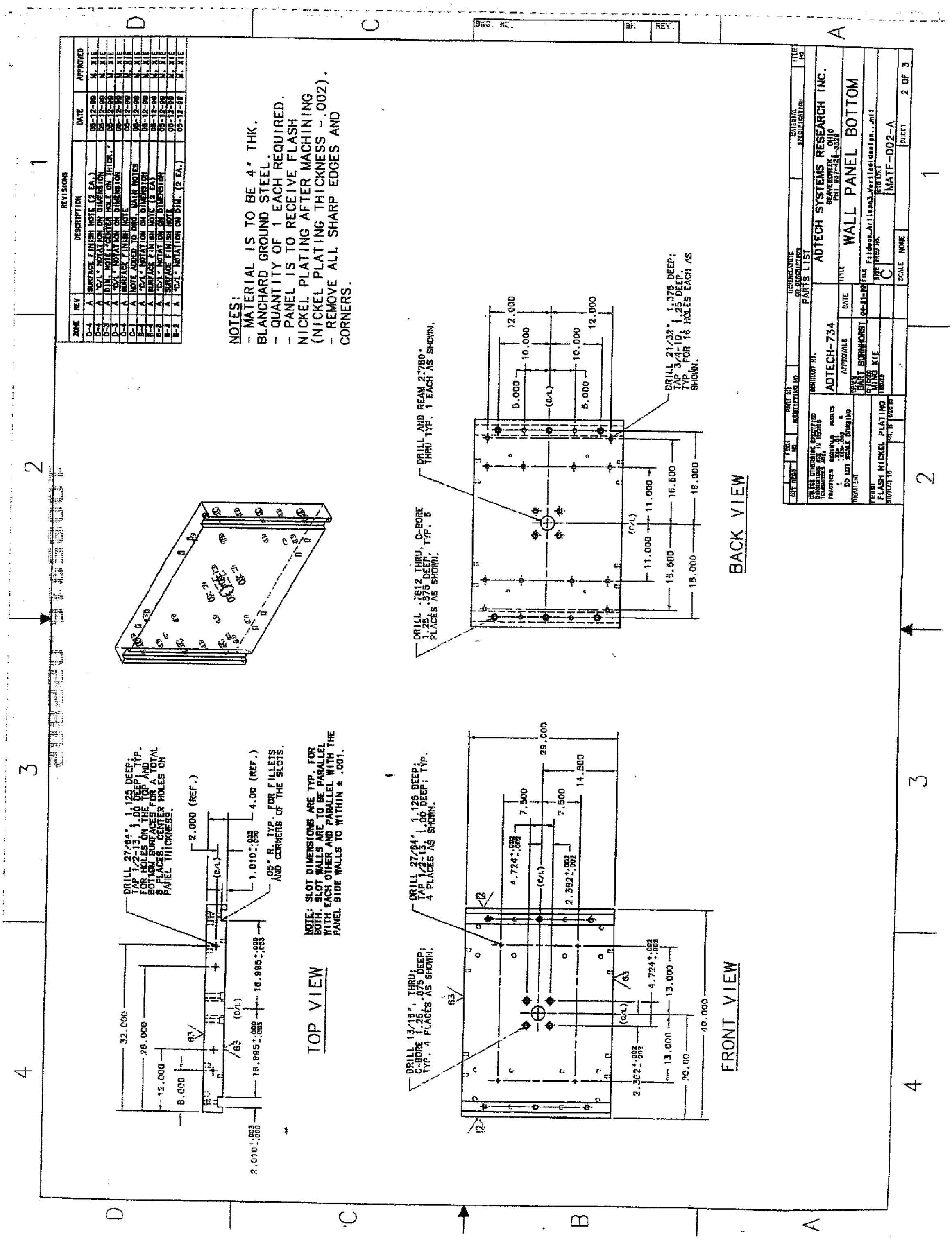
APPENDIX B

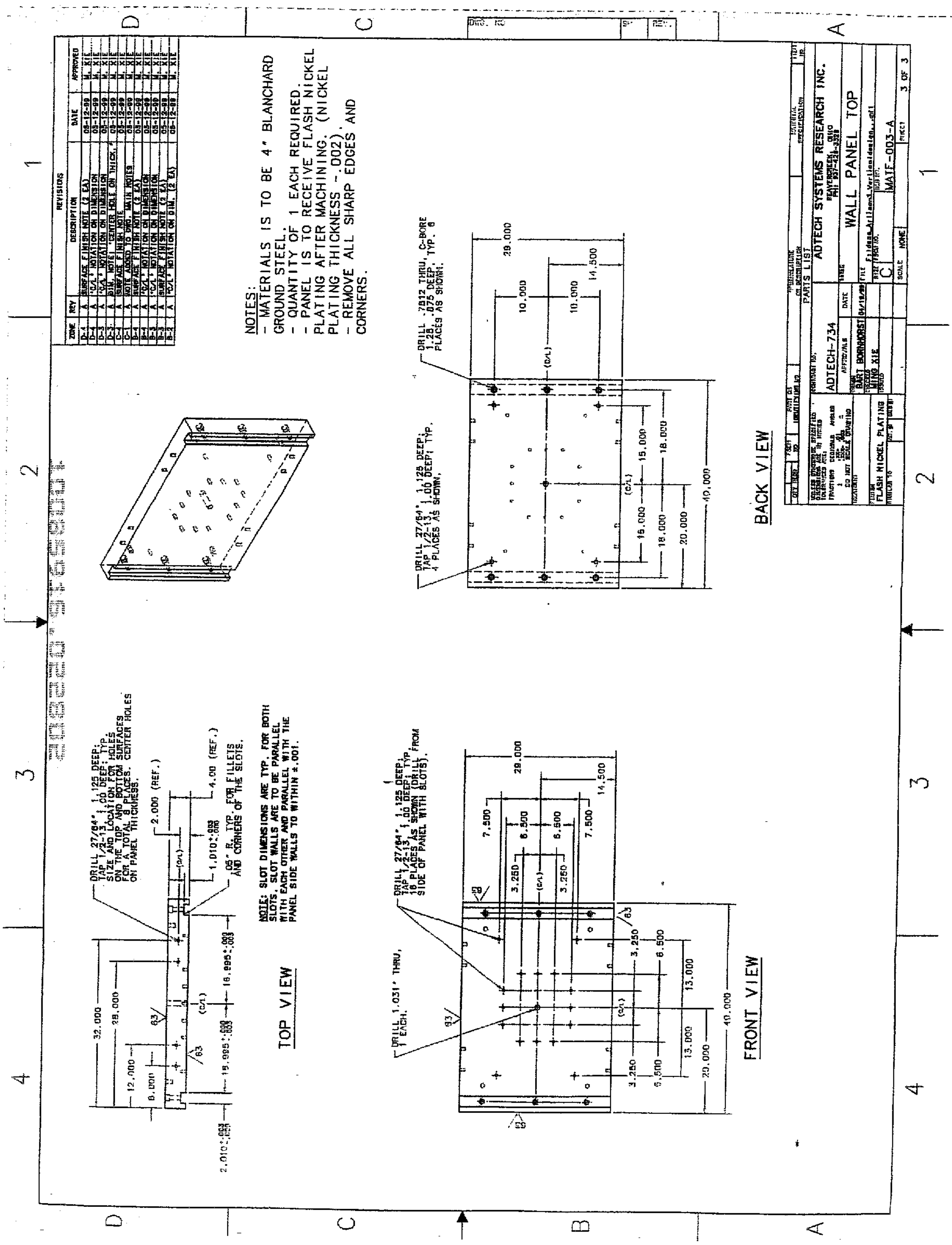
DRAWINGS

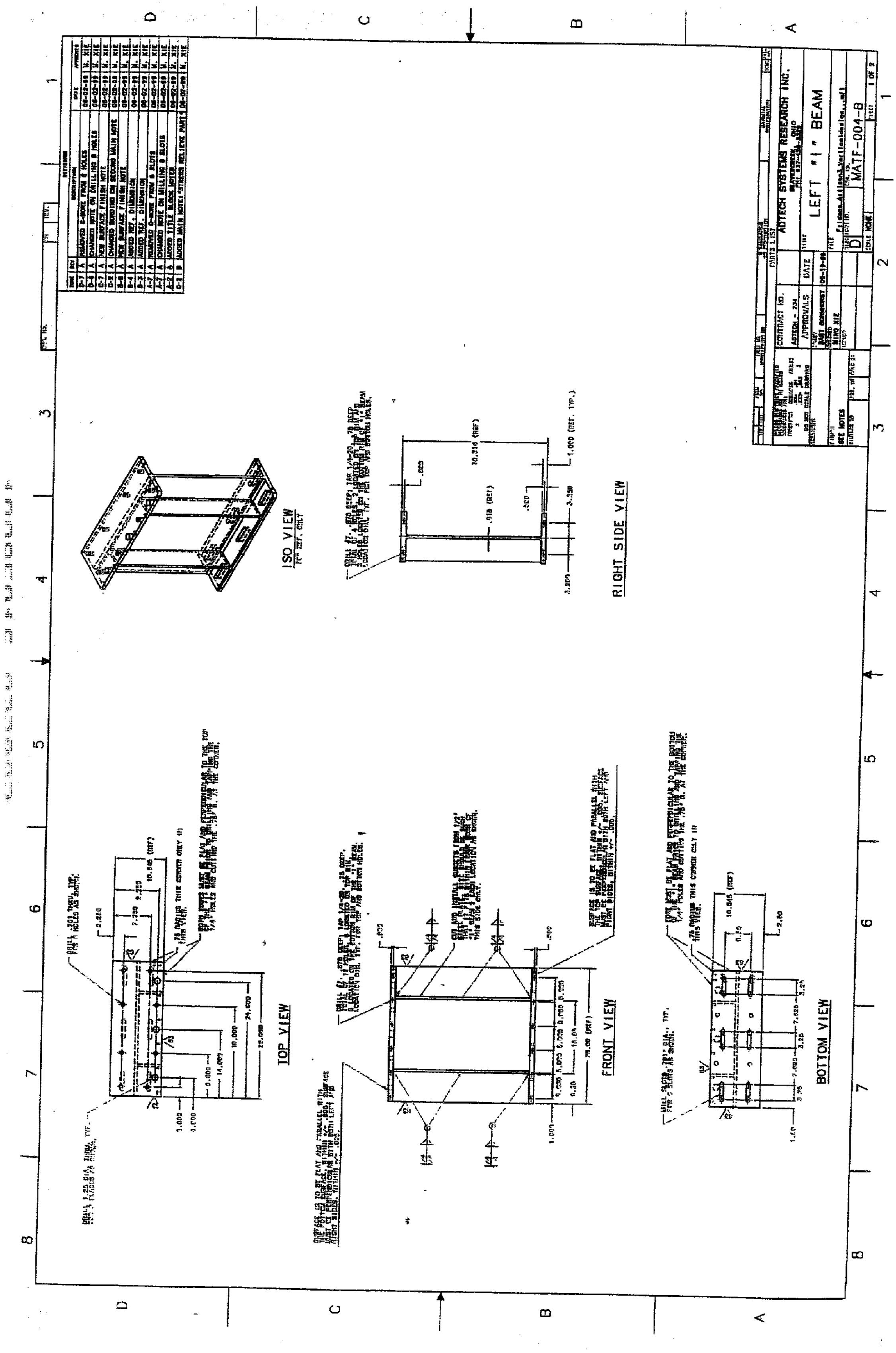

(40,00)
(29,00)
(4,00)
(57,99)
(30,31)

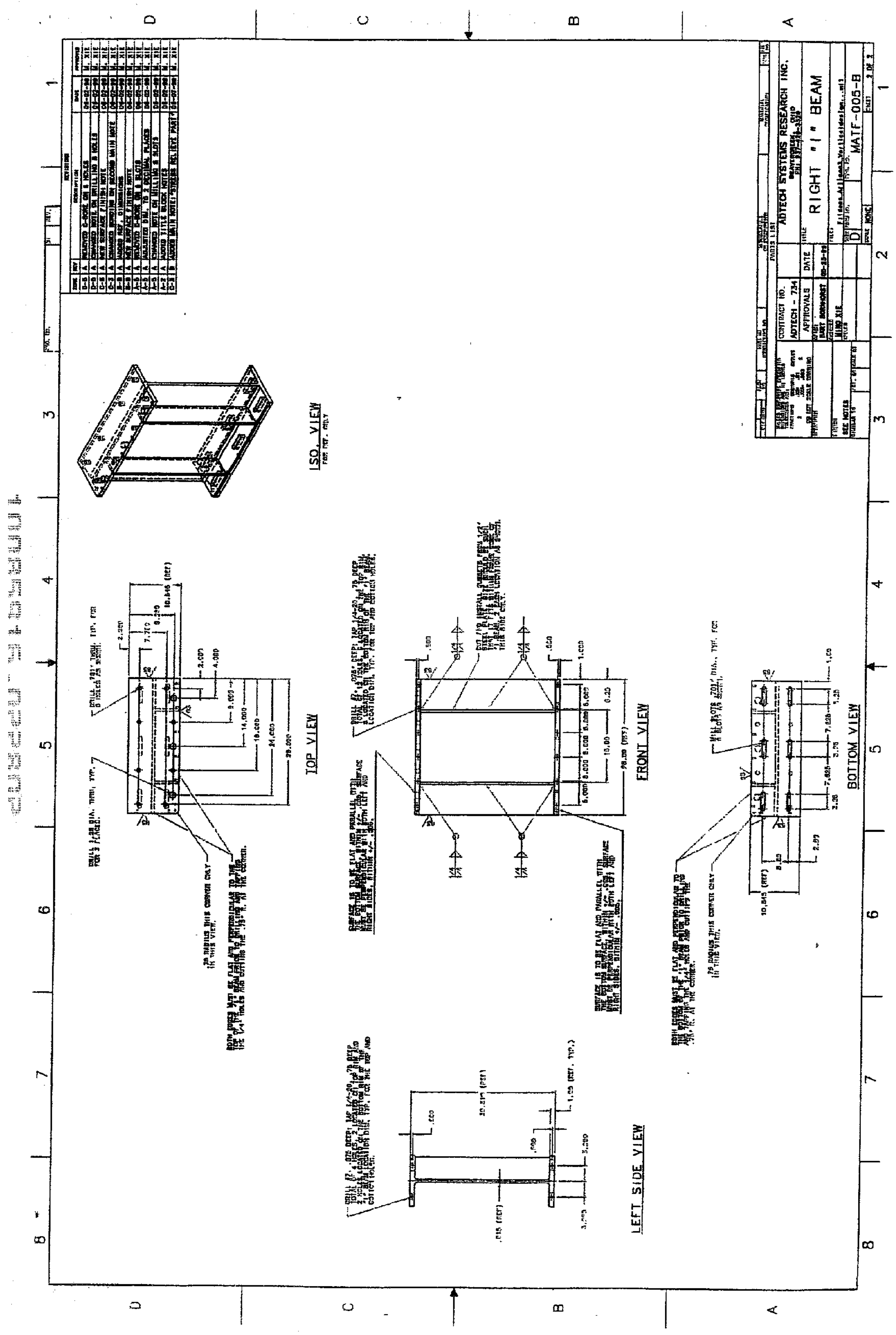

(40,00)
(4,00)
(57,00)
(30,31)

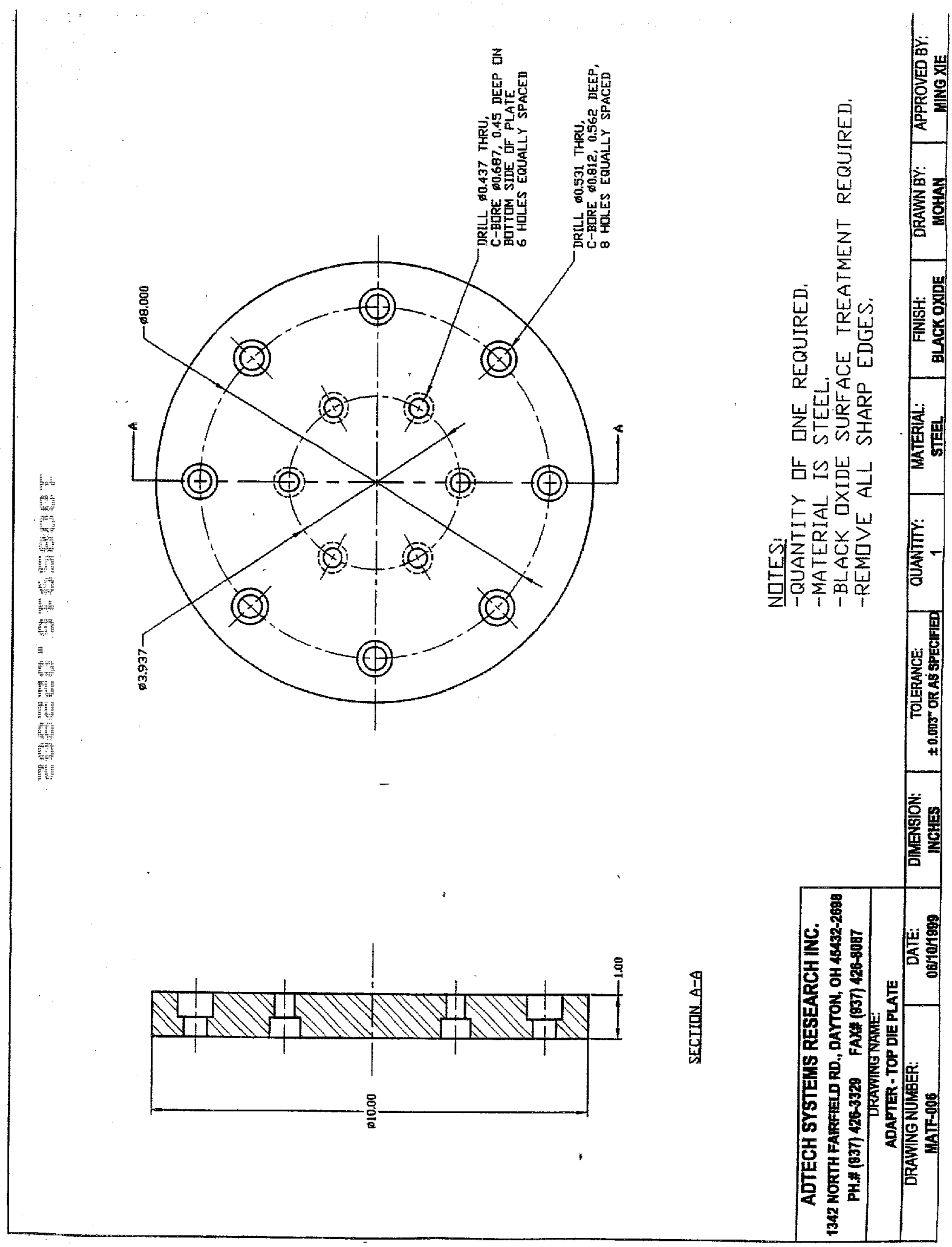

NOTES:
- MATERIAL IS TO BE 4" THK. BLANCHARD GROUND STEEL.
- QUANTITY OF 2 EACH.
- PANEL IS TO RECEIVE FLASH NICKEL PLATING AFTER MACHINING (NICKEL PLATING THICKNESS -.002).
- REMOVE ALL SHARP EDGES AND CORNERS.
RIGHT SIDE VIEW
TOP VIEW
FRONT VIEW
NOTE: TOP AND BOTTOM END DIMENSIONS ARE TYP.
ADTECH SYSTEMS RESEARCH INC.
WALL PANEL LEFT AND RIGHT
ADTECH-734
FLASH NICKEL PLATING
MATF-001-A

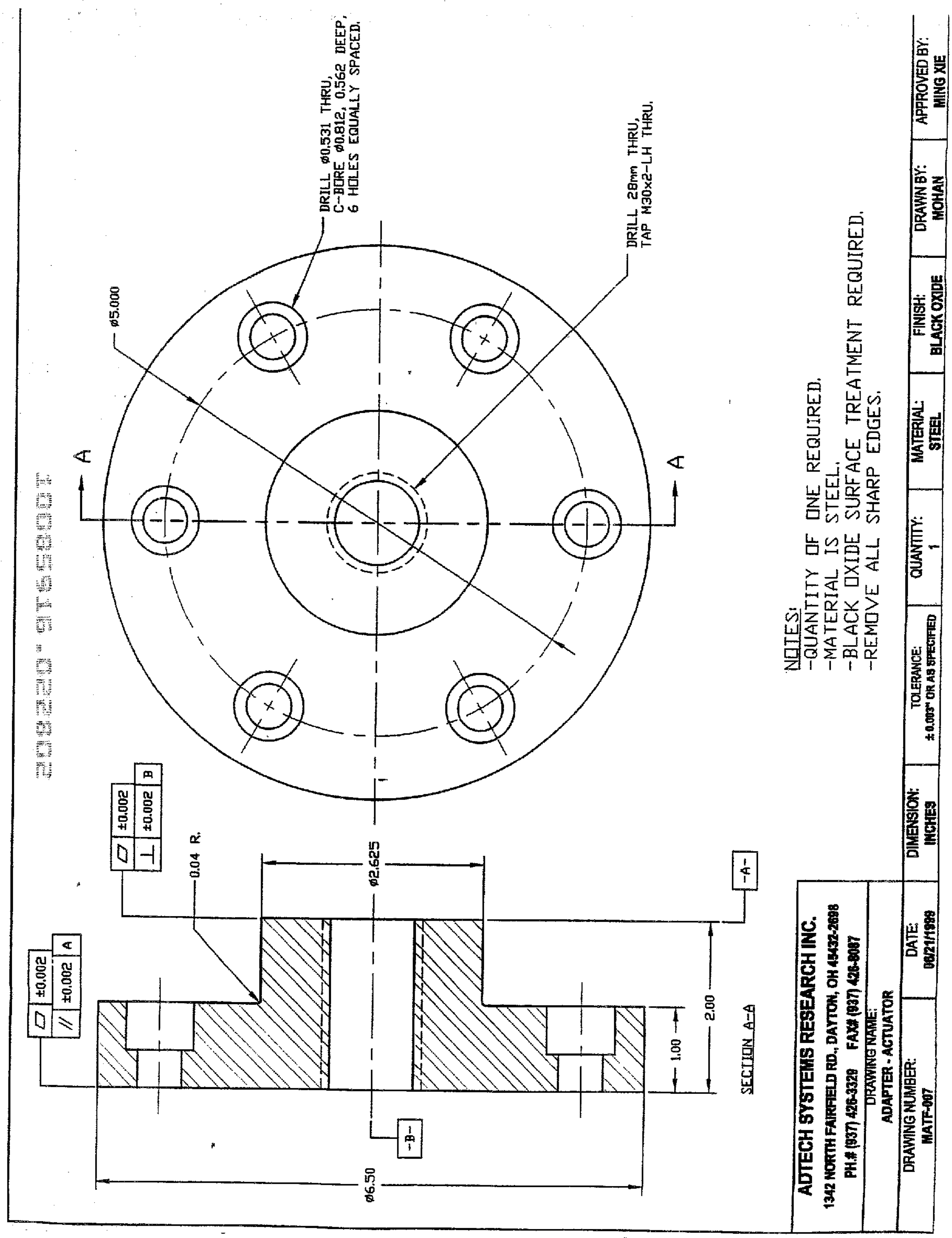

NOTES:
- MATERIAL IS TO BE 4" THK. BLANCHARD GROUND STEEL.
- QUANTITY OF 1 EACH REQUIRED.
- PANEL IS TO RECEIVE FLASH NICKEL PLATING AFTER MACHINING (NICKEL PLATING THICKNESS -.002).
- REMOVE ALL SHARP EDGES AND CORNERS.
TOP VIEW
FRONT VIEW
BACK VIEW
ADTECH SYSTEMS RESEARCH INC.
WALL PANEL BOTTOM
ADTECH-734
FLASH NICKEL PLATING
MATF-002-A

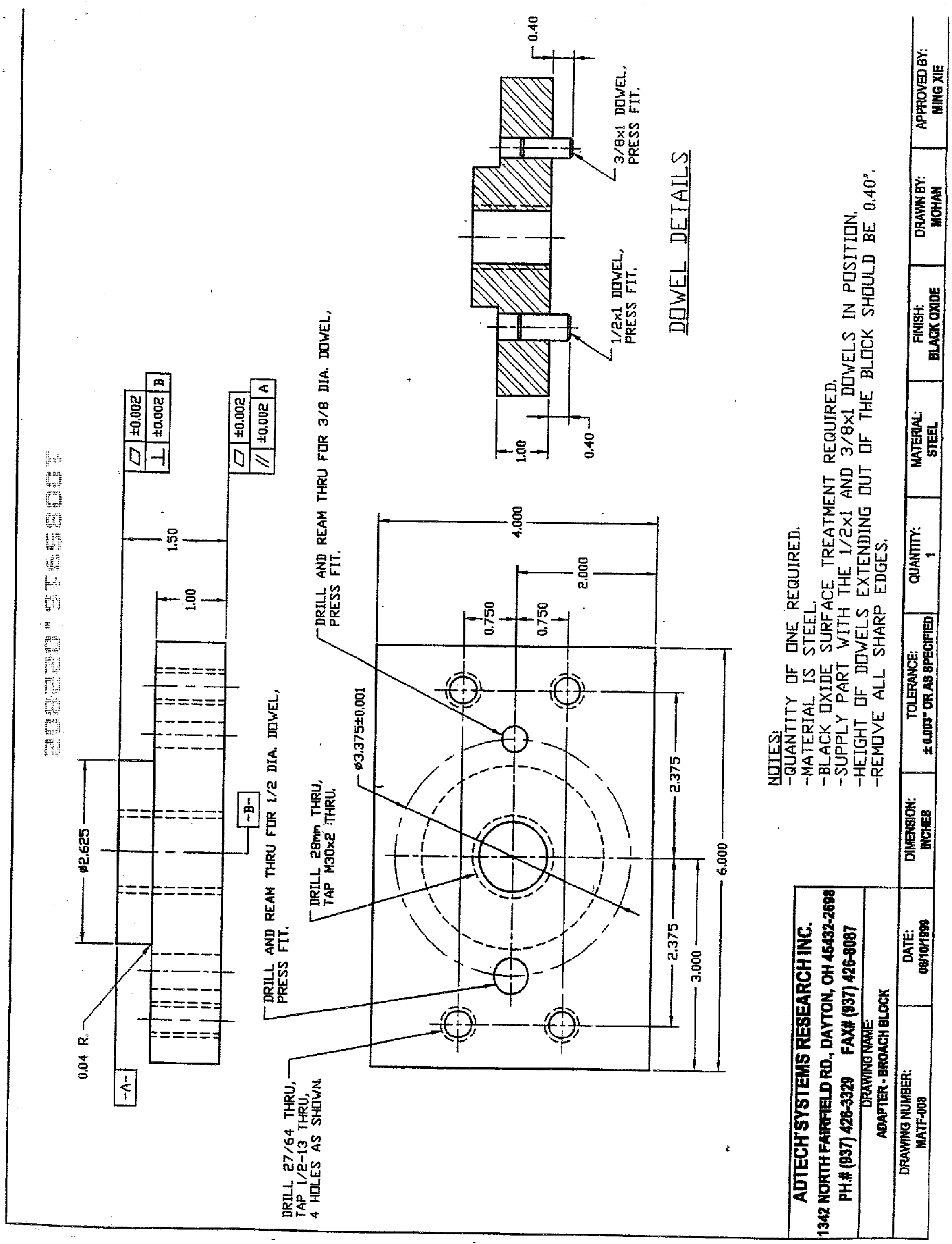

NOTES:
- MATERIALS IS TO BE 4" BLANCHARD GROUND STEEL.
- QUANTITY OF 1 EACH REQUIRED.
- PANEL IS TO RECEIVE FLASH NICKEL PLATING AFTER MACHINING. (NICKEL PLATING THICKNESS -.002).
- REMOVE ALL SHARP EDGES AND CORNERS.
TOP VIEW
FRONT VIEW
BACK VIEW
ADTECH SYSTEMS RESEARCH INC.
WALL PANEL TOP
ADTECH-734
MATF-003-A
FLASH NICKEL PLATING


AOTECH SYSTEMS RESEARCH INC.
LEFT #1 BEAM
MATF-004-B
ISO VIEW
RIGHT SIDE VIEW
TOP VIEW
FRONT VIEW
BOTTOM VIEW

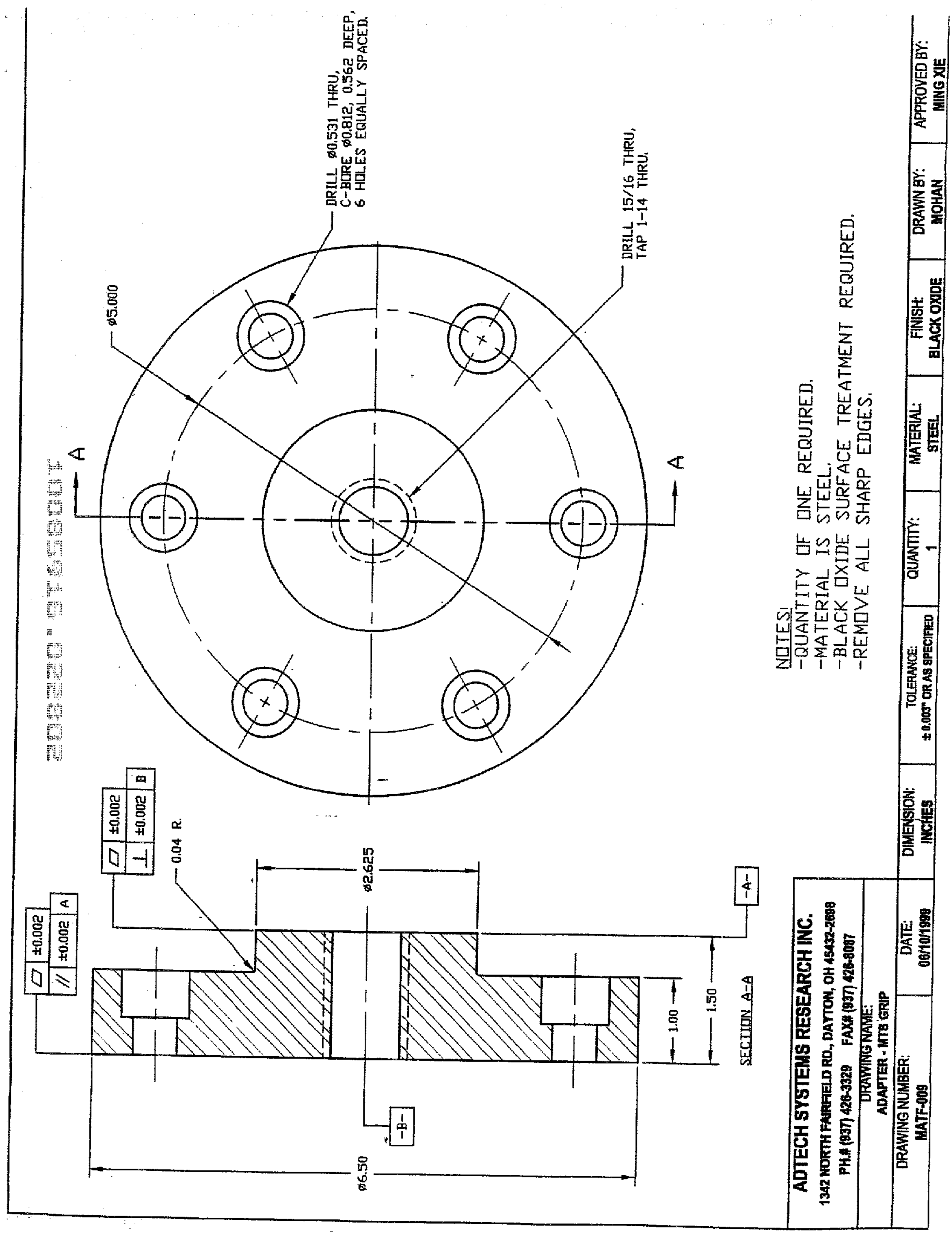

ISO. VIEW
TOP VIEW
FRONT VIEW
BOTTOM VIEW
LEFT SIDE VIEW
ADTECH SYSTEMS RESEARCH INC.
RIGHT "I" BEAM
MATF-005-B

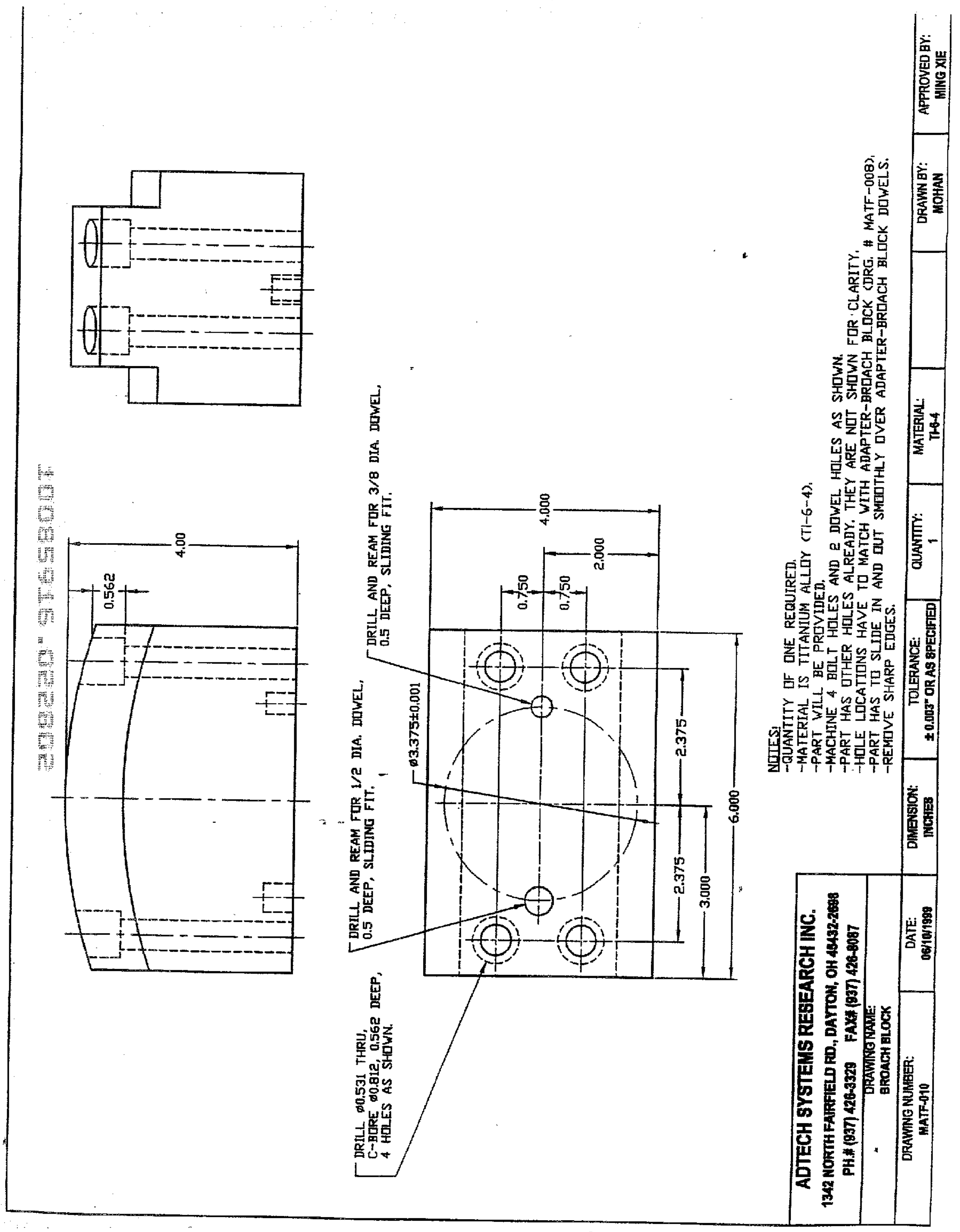

DRILL ø0.437 THRU,
C-BORE ø0.687, 0.45 DEEP ON
BOTTOM SIDE OF PLATE
6 HOLES EQUALLY SPACED
DRILL ø0.531 THRU,
C-BORE ø0.812, 0.562 DEEP,
8 HOLES EQUALLY SPACED
ø8.000
ø3.937
A
A
ø10.00
1.00
SECTION A-A
NOTES:
-QUANTITY OF ONE REQUIRED.
-MATERIAL IS STEEL.
-BLACK OXIDE SURFACE TREATMENT REQUIRED.
-REMOVE ALL SHARP EDGES.
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD., DAYTON, OH 45432-2698
PH.# (937) 426-3329 FAX# (937) 426-8087
DRAWING NAME:
ADAPTER - TOP DIE PLATE
DRAWING NUMBER:
MATF-006
DATE:
06/10/1999
DIMENSION:
INCHES
TOLERANCE:
± 0.003" OR AS SPECIFIED
QUANTITY:
1
MATERIAL:
STEEL
FINISH:
BLACK OXIDE
DRAWN BY:
MOHAN
APPROVED BY:
MING XIE

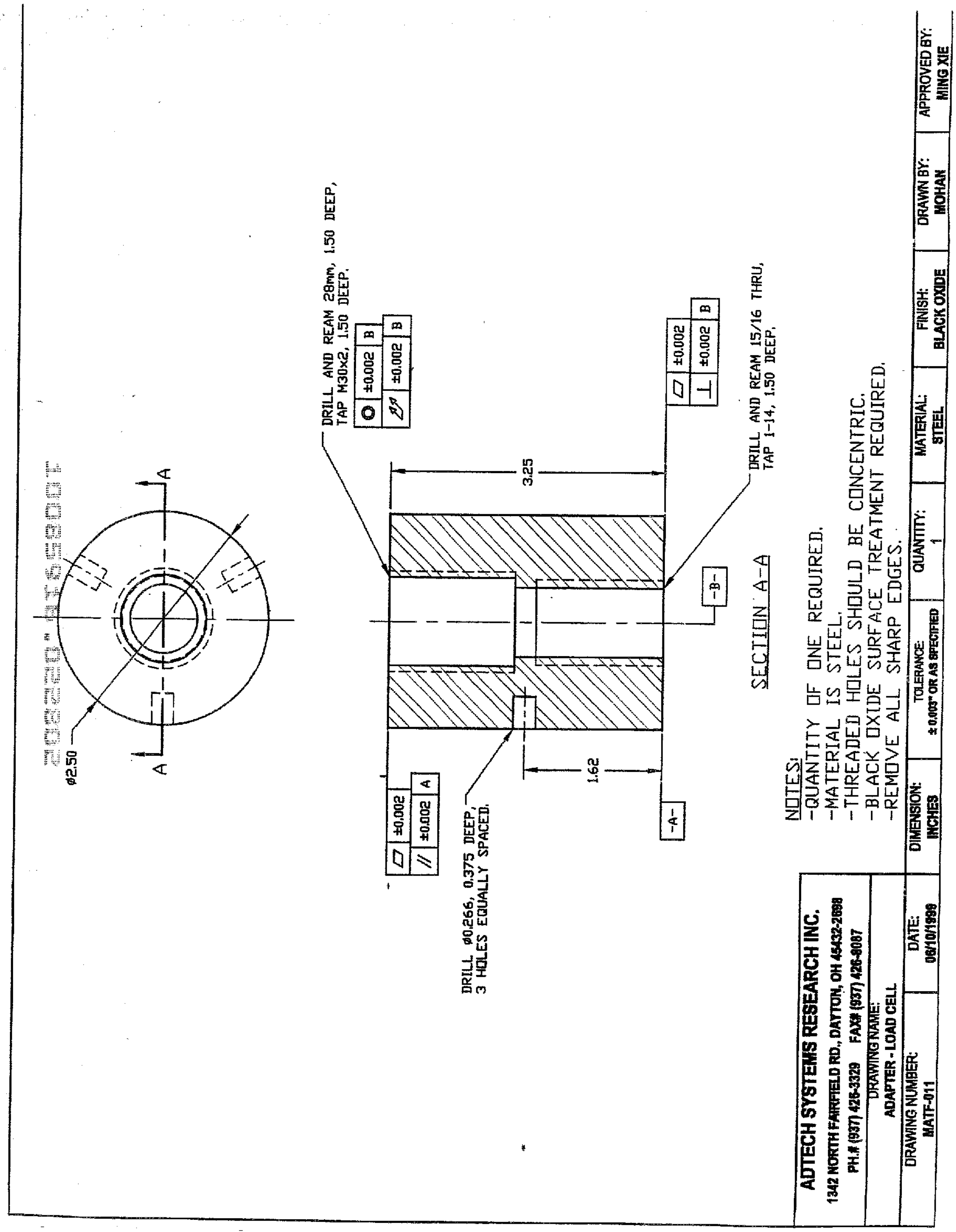

DRILL ø0.531 THRU,
C-BORE ø0.812, 0.562 DEEP,
6 HOLES EQUALLY SPACED.
DRILL 28mm THRU,
TAP M30x2-LH THRU.
ø5.000
A
A
NOTES:
-QUANTITY OF ONE REQUIRED.
-MATERIAL IS STEEL.
-BLACK OXIDE SURFACE TREATMENT REQUIRED.
-REMOVE ALL SHARP EDGES.
±0.002
±0.002 A
±0.002
±0.002 B
0.04 R.
ø2.625
-A-
-B-
1.00
2.00
SECTION A-A
ø6.50
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD., DAYTON, OH 45432-2698
PH.# (937) 426-3329 FAX# (937) 426-8087
DRAWING NAME:
ADAPTER - ACTUATOR
DRAWING NUMBER:
MATF-007
DATE:
06/21/1999
DIMENSION:
INCHES
TOLERANCE:
± 0.003" OR AS SPECIFIED
QUANTITY:
1
MATERIAL:
STEEL
FINISH:
BLACK OXIDE
DRAWN BY:
MOHAN
APPROVED BY:
MING XIE

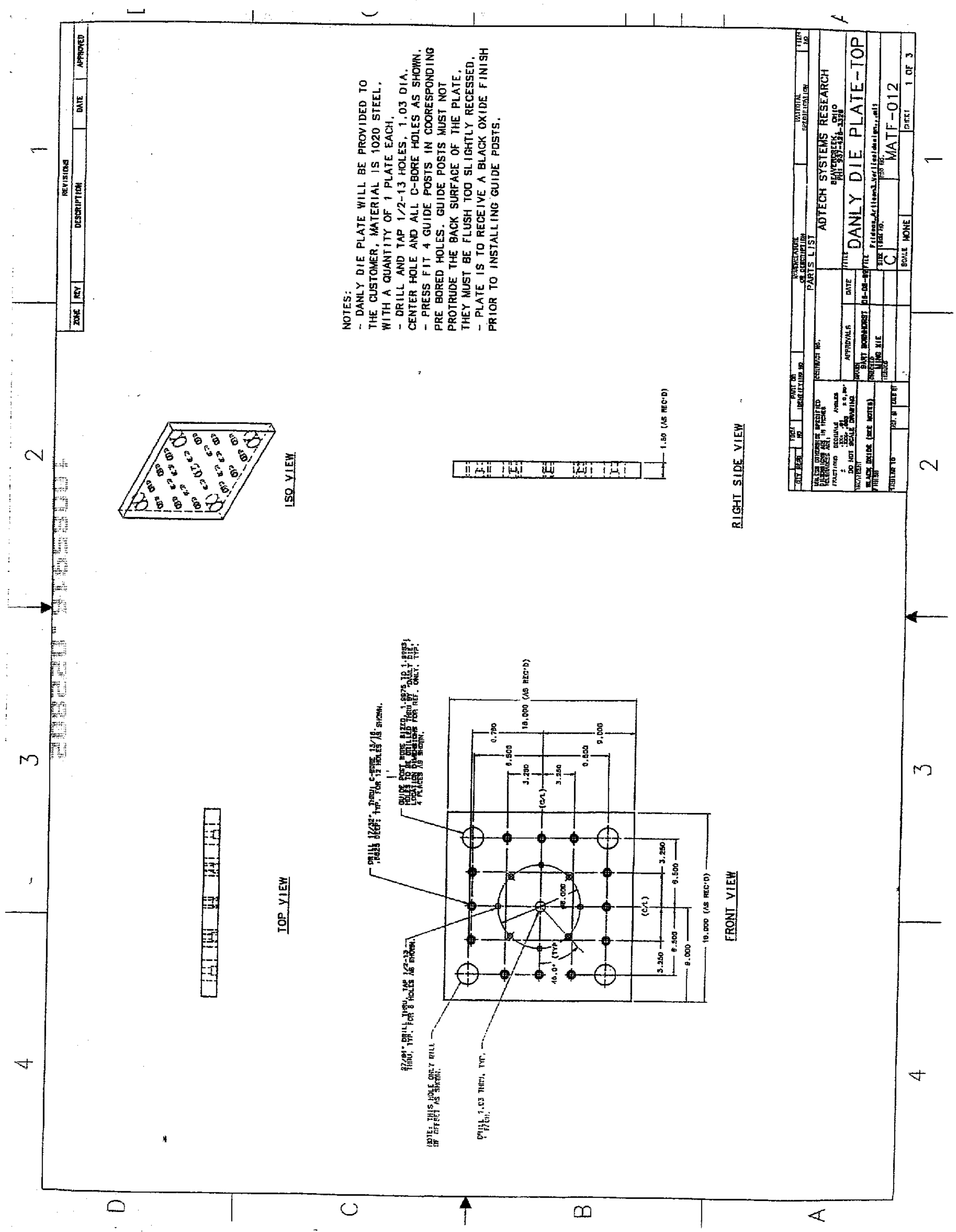


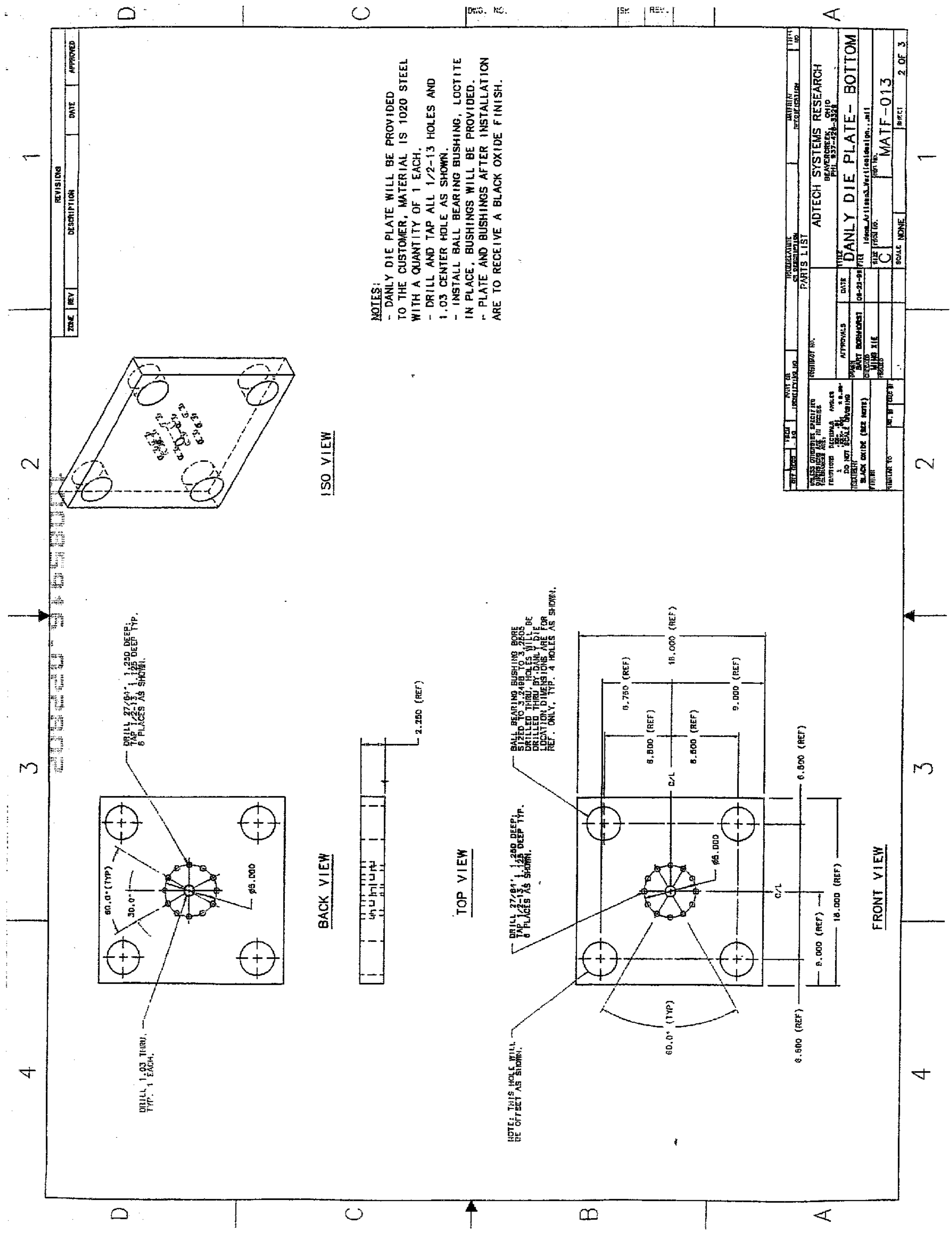
ø2.625
0.04 R.
-A-
-B-
1.00
1.50
±0.002
±0.002 B
±0.002
±0.002 A
DRILL AND REAM THRU FOR 1/2 DIA. DOWEL, PRESS FIT.
DRILL AND REAM THRU FOR 3/8 DIA. DOWEL, PRESS FIT.
DRILL 28mm THRU, TAP M30x2 THRU.
ø3.375±0.001
DRILL 27/64 THRU, TAP 1/2-13 THRU, 4 HOLES AS SHOWN.
0.750
0.750
4.000
2.000
2.375
2.375
3.000
6.000
1.00
0.40
0.40
1/2x1 DOWEL, PRESS FIT.
3/8x1 DOWEL, PRESS FIT.
DOWEL DETAILS
NOTES:
-QUANTITY OF ONE REQUIRED.
-MATERIAL IS STEEL.
-BLACK OXIDE SURFACE TREATMENT REQUIRED.
-SUPPLY PART WITH THE 1/2x1 AND 3/8x1 DOWELS IN POSITION.
-HEIGHT OF DOWELS EXTENDING OUT OF THE BLOCK SHOULD BE 0.40".
-REMOVE ALL SHARP EDGES.
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD., DAYTON, OH 45432-2698
PH.# (937) 426-3329 FAX# (937) 426-8087
DRAWING NAME:
ADAPTER - BROACH BLOCK
DRAWING NUMBER:
MATF-008
DATE:
08/10/1999
DIMENSION:
INCHES
TOLERANCE:
± 0.003" OR AS SPECIFIED
QUANTITY:
1
MATERIAL:
STEEL
FINISH:
BLACK OXIDE
DRAWN BY:
MOHAN
APPROVED BY:
MING XIE

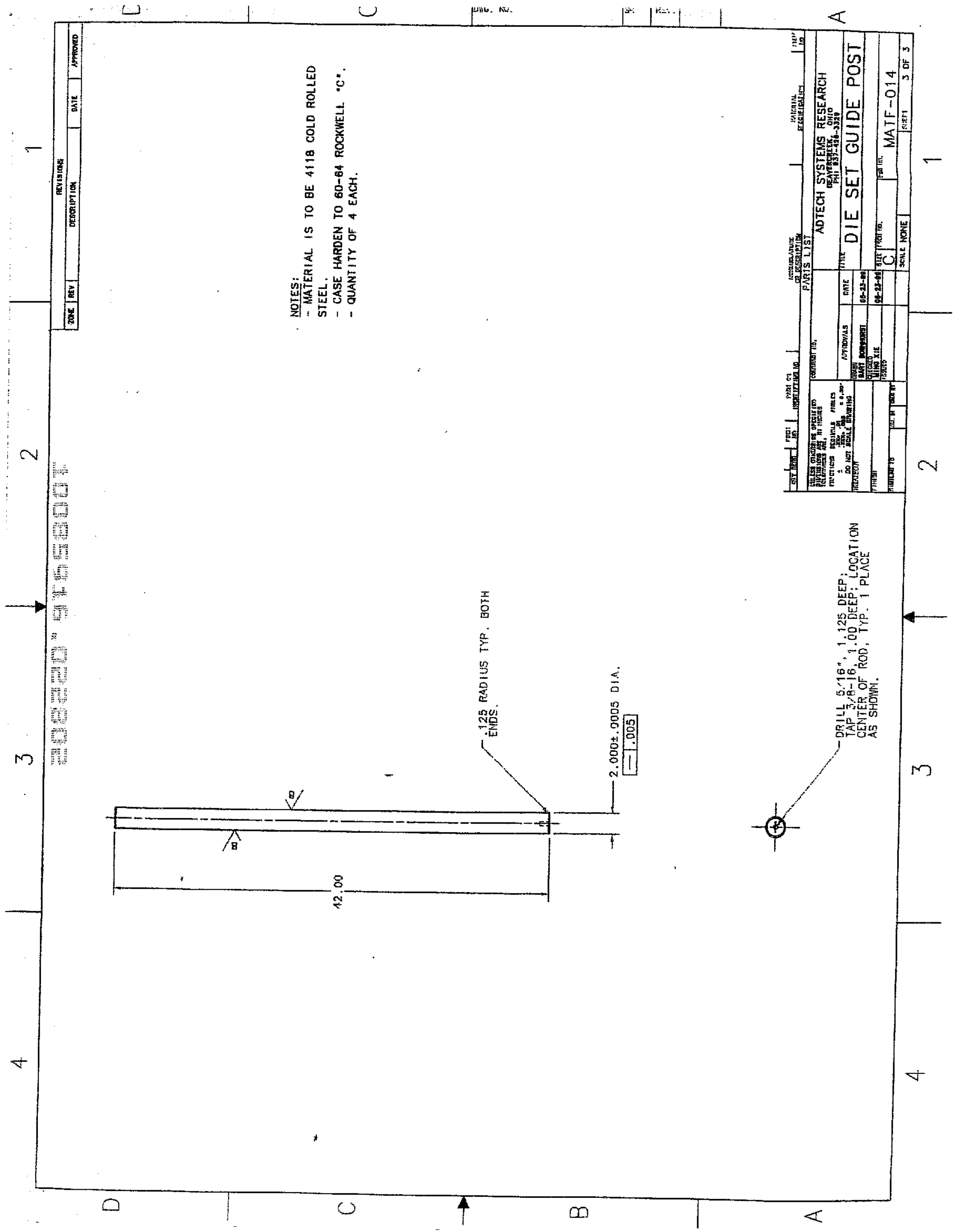

DRILL ø0.531 THRU, C-BORE ø0.812, 0.562 DEEP, 6 HOLES EQUALLY SPACED.
DRILL 15/16 THRU, TAP 1-14 THRU.
ø5.000
A
A
±0.002
±0.002 A
±0.002
±0.002 B
0.04 R.
ø2.625
-A-
-B-
1.00
1.50
ø6.50
SECTION A-A
NOTES:
-QUANTITY OF ONE REQUIRED.
-MATERIAL IS STEEL.
-BLACK OXIDE SURFACE TREATMENT REQUIRED.
-REMOVE ALL SHARP EDGES.
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD., DAYTON, OH 45432-2698
PH.# (937) 426-3329 FAX# (937) 426-8087
DRAWING NAME:
ADAPTER - MTS GRIP
DRAWING NUMBER:
MATF-009
DATE:
08/10/1999
DIMENSION:
INCHES
TOLERANCE:
± 0.003" OR AS SPECIFIED
QUANTITY:
1
MATERIAL:
STEEL
FINISH:
BLACK OXIDE
DRAWN BY:
MOHAN
APPROVED BY:
MING XIE

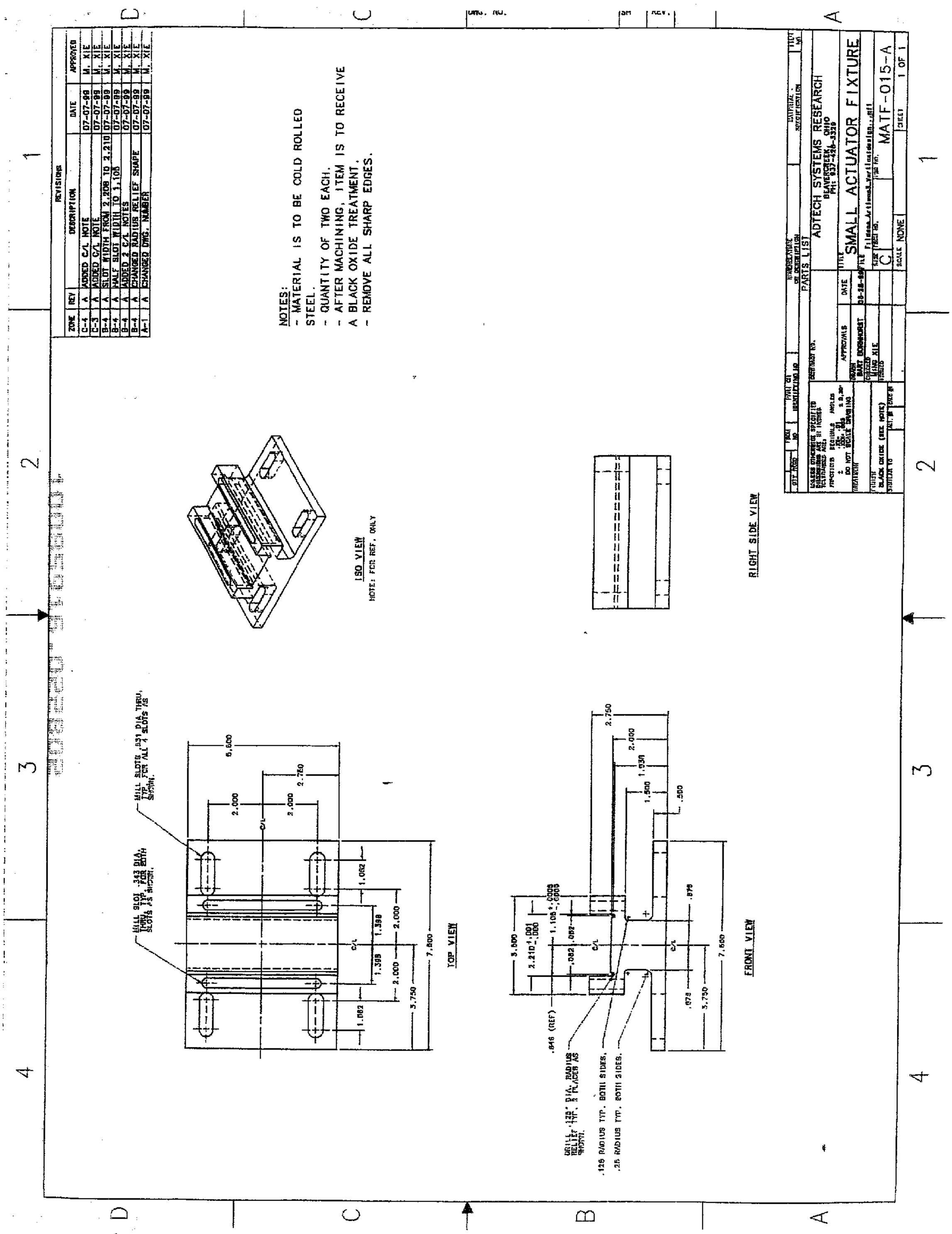

4.00
0.562
4.000
2.000
0.750
0.750
6.000
2.375
2.375
3.000
ø3.375±0.001
DRILL AND REAM FOR 3/8 DIA. DOWEL, 0.5 DEEP, SLIDING FIT.
DRILL AND REAM FOR 1/2 DIA. DOWEL, 0.5 DEEP, SLIDING FIT.
DRILL ø0.531 THRU, C-BORE ø0.812, 0.562 DEEP, 4 HOLES AS SHOWN.
NOTES:
-QUANTITY OF ONE REQUIRED.
-MATERIAL IS TITANIUM ALLOY (TI-6-4).
-PART WILL BE PROVIDED.
-MACHINE 4 BOLT HOLES AND 2 DOWEL HOLES AS SHOWN.
-PART HAS OTHER HOLES ALREADY. THEY ARE NOT SHOWN FOR CLARITY.
-HOLE LOCATIONS HAVE TO MATCH WITH ADAPTER-BROACH BLOCK (DRG. # MATF-008).
-PART HAS TO SLIDE IN AND OUT SMOOTHLY OVER ADAPTER-BROACH BLOCK DOWELS.
-REMOVE SHARP EDGES.
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD., DAYTON, OH 45432-2698
PH.# (937) 426-3329 FAX# (937) 426-8087
DRAWING NAME:
BROACH BLOCK
DRAWING NUMBER:
MATF-010
DATE:
06/10/1999
DIMENSION:
INCHES
TOLERANCE:
± 0.003" OR AS SPECIFIED
QUANTITY:
1
MATERIAL:
TI-6-4
DRAWN BY:
MOHAN
APPROVED BY:
MING XIE

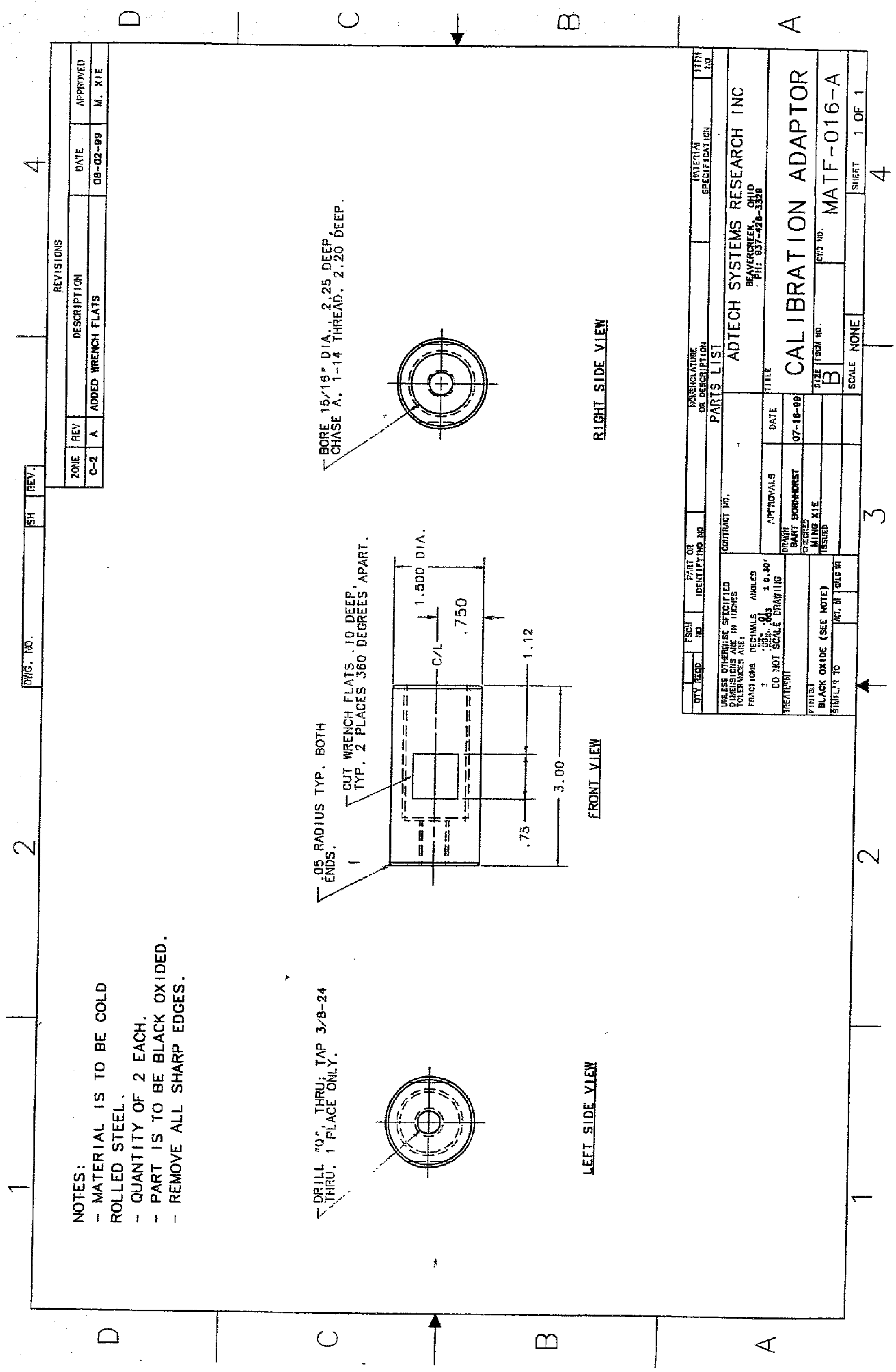

ø2.50
A
A
DRILL AND REAM 28mm, 1.50 DEEP,
TAP M30x2, 1.50 DEEP.
±0.002 B
±0.002 B
3.25
±0.002
±0.002 B
DRILL AND REAM 15/16 THRU,
TAP 1-14, 1.50 DEEP.
-B-
-A-
1.62
±0.002
±0.002 A
DRILL ø0.266, 0.375 DEEP,
3 HOLES EQUALLY SPACED.
SECTION A-A
NOTES:
-QUANTITY OF ONE REQUIRED.
-MATERIAL IS STEEL.
-THREADED HOLES SHOULD BE CONCENTRIC.
-BLACK OXIDE SURFACE TREATMENT REQUIRED.
-REMOVE ALL SHARP EDGES.
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD., DAYTON, OH 45432-2698
PH.# (937) 426-3329 FAX# (937) 426-8087
DRAWING NAME:
ADAPTER - LOAD CELL
DRAWING NUMBER:
MATF-011
DATE:
06/10/1999
DIMENSION:
INCHES
TOLERANCE:
± 0.003" OR AS SPECIFIED
QUANTITY:
1
MATERIAL:
STEEL
FINISH:
BLACK OXIDE
DRAWN BY:
MOHAN
APPROVED BY:
MING XIE

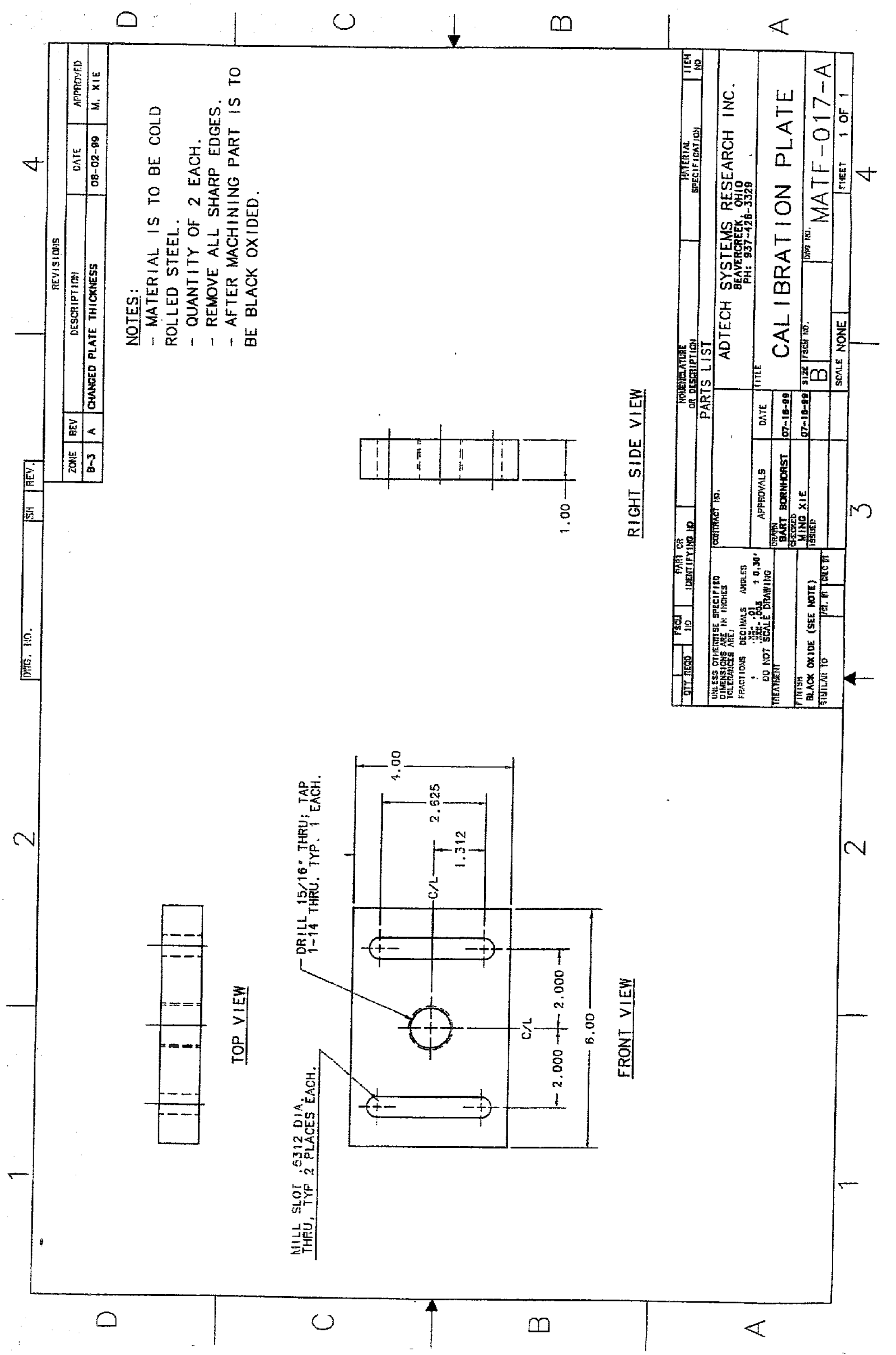

NOTES:
- DANLY DIE PLATE WILL BE PROVIDED TO THE CUSTOMER, MATERIAL IS 1020 STEEL, WITH A QUANTITY OF 1 PLATE EACH.
- DRILL AND TAP 1/2-13 HOLES, 1.03 DIA. CENTER HOLE AND ALL C-BORE HOLES AS SHOWN.
- PRESS FIT 4 GUIDE POSTS IN COORESPONDING PRE BORED HOLES. GUIDE POSTS MUST NOT PROTRUDE THE BACK SURFACE OF THE PLATE. THEY MUST BE FLUSH TOO SLIGHTLY RECESSED.
- PLATE IS TO RECEIVE A BLACK OXIDE FINISH PRIOR TO INSTALLING GUIDE POSTS.
ISO VIEW
RIGHT SIDE VIEW
TOP VIEW
FRONT VIEW
PARTS LIST
ADTECH SYSTEMS RESEARCH
DANLY DIE PLATE-TOP
MATF-012
SCALE NONE
1 OF 3

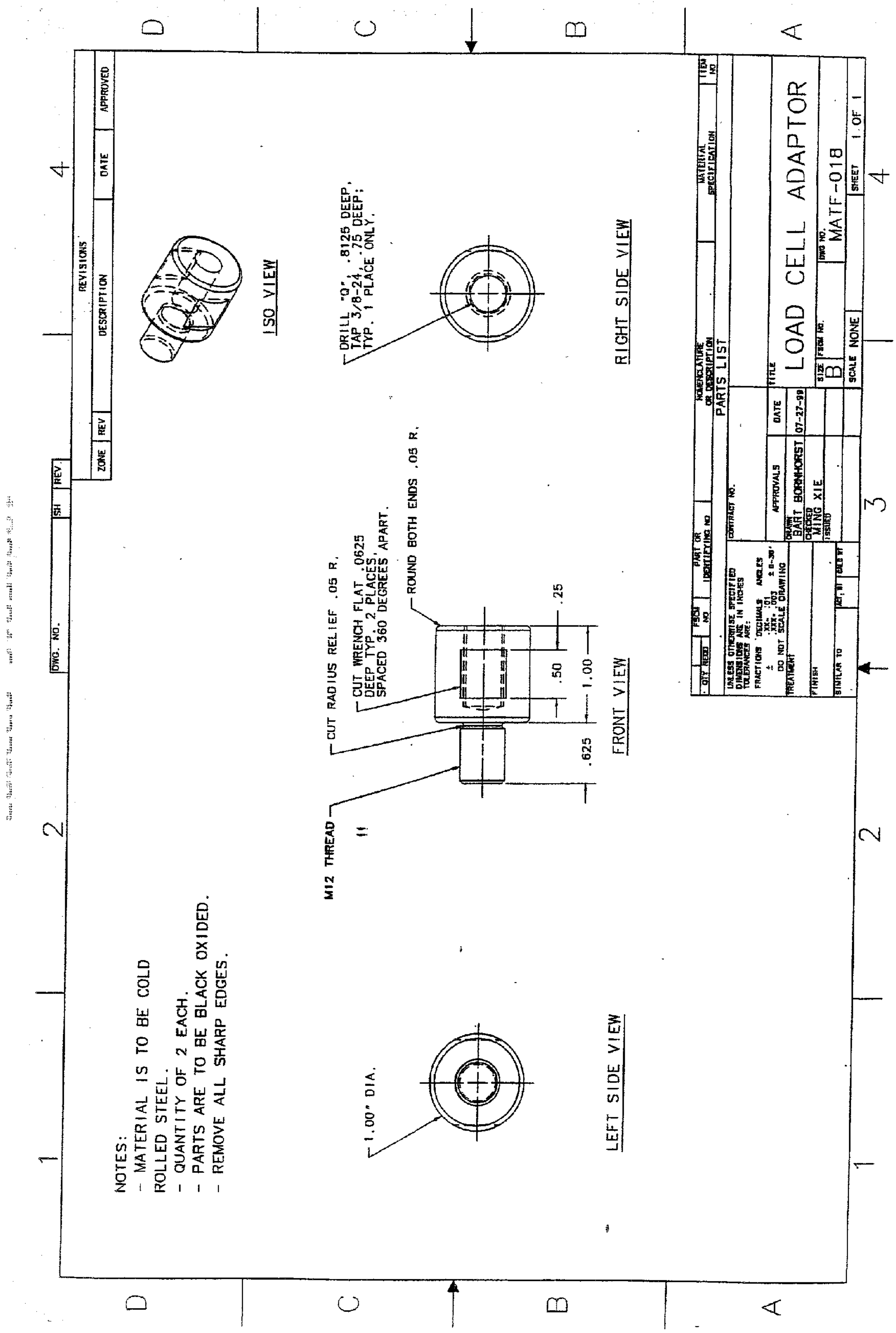

NOTES:
- DANLY DIE PLATE WILL BE PROVIDED TO THE CUSTOMER, MATERIAL IS 1020 STEEL WITH A QUANTITY OF 1 EACH.
- DRILL AND TAP ALL 1/2-13 HOLES AND 1.03 CENTER HOLE AS SHOWN.
- INSTALL BALL BEARING BUSHING, LOCTITE IN PLACE, BUSHINGS WILL BE PROVIDED.
- PLATE AND BUSHINGS AFTER INSTALLATION ARE TO RECEIVE A BLACK OXIDE FINISH.
BACK VIEW
ISO VIEW
TOP VIEW
FRONT VIEW
DRILL 1.03 THRU. TYP. 1 EACH.
DRILL 27/64", 1.250 DEEP; TAP 1/2-13, 1.125 DEEP TYP. 8 PLACES AS SHOWN.
60.0° (TYP)
30.0°
ø5.000
2.250 (REF)
NOTE: THIS HOLE WILL BE OFFSET AS SHOWN.
BALL BEARING BUSHING BORE SIZED TO 3.2498 TO 3.2505 DRILLED THRU. HOLES WILL BE DRILLED THRU BY DANLY DIE LOCATION DIMENSIONS ARE FOR REF. ONLY. TYP. 4 HOLES AS SHOWN.
8.750 (REF)
6.500 (REF)
C/L
18.000 (REF)
9.000 (REF)
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK, OHIO
APPROVALS
DATE
DRAWN
BART BORNHORST
CHECKED
MING XIE
TITLE
DANLY DIE PLATE- BOTTOM
SIZE
C
DWG NO.
MATF-013
SCALE NONE
SHEET 2 OF 3
BLACK OXIDE (SEE NOTE)
DO NOT SCALE DRAWING

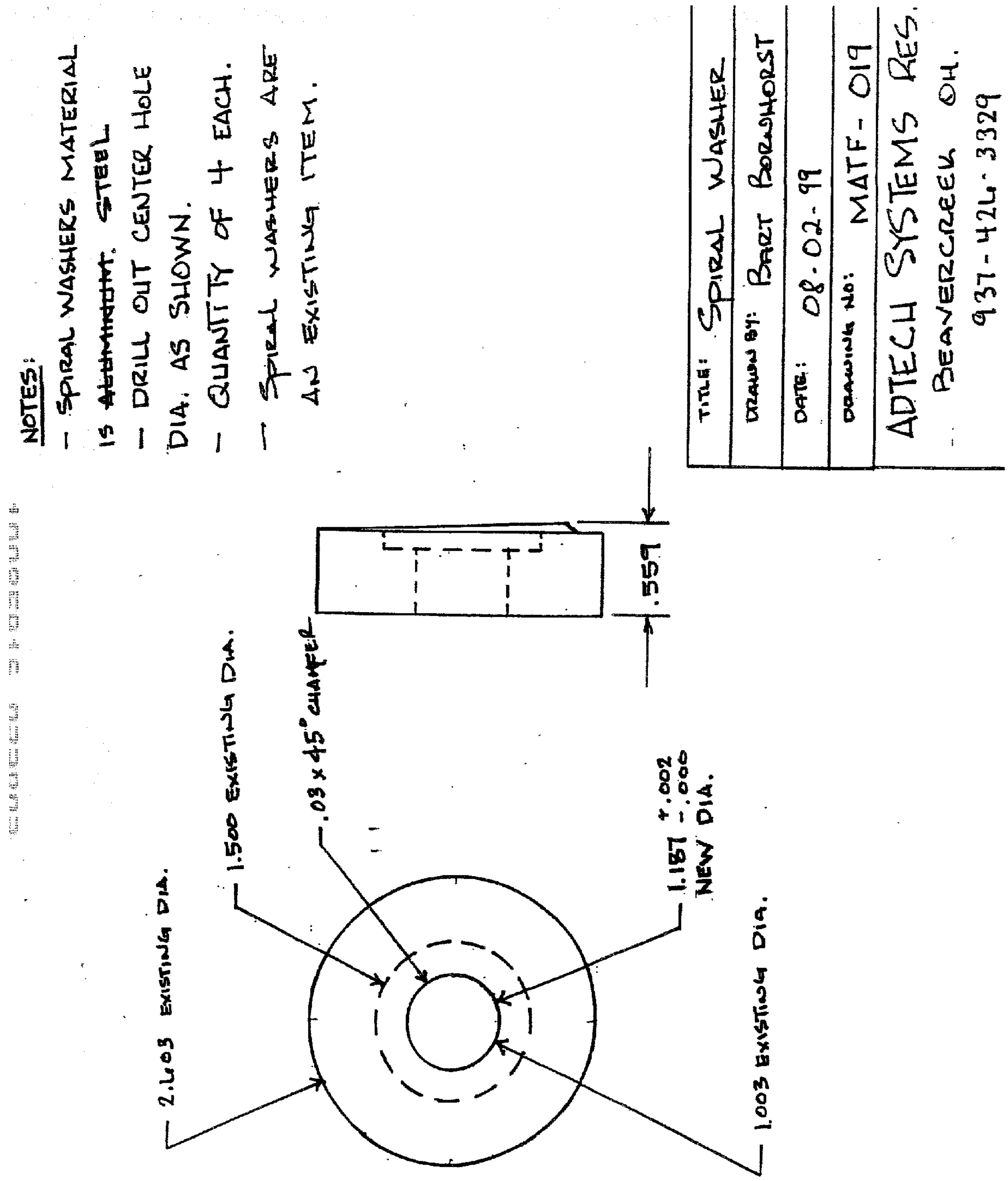

NOTES:
- MATERIAL IS TO BE 4118 COLD ROLLED STEEL.
- CASE HARDEN TO 60-64 ROCKWELL "C".
- QUANTITY OF 4 EACH.
.125 RADIUS TYP. BOTH ENDS.
2.000±.0005 DIA.
.005
42.00
DRILL 5/16", 1.125 DEEP; TAP 3/8-16, 1.00 DEEP; LOCATION CENTER OF ROD, TYP. 1 PLACE AS SHOWN.
PARTS LIST
ADTECH SYSTEMS RESEARCH
DIE SET GUIDE POST
MATF-014
SCALE NONE
3 OF 3
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DO NOT SCALE DRAWING
APPROVALS
DATE
C
A
B
D
1
2
3
4

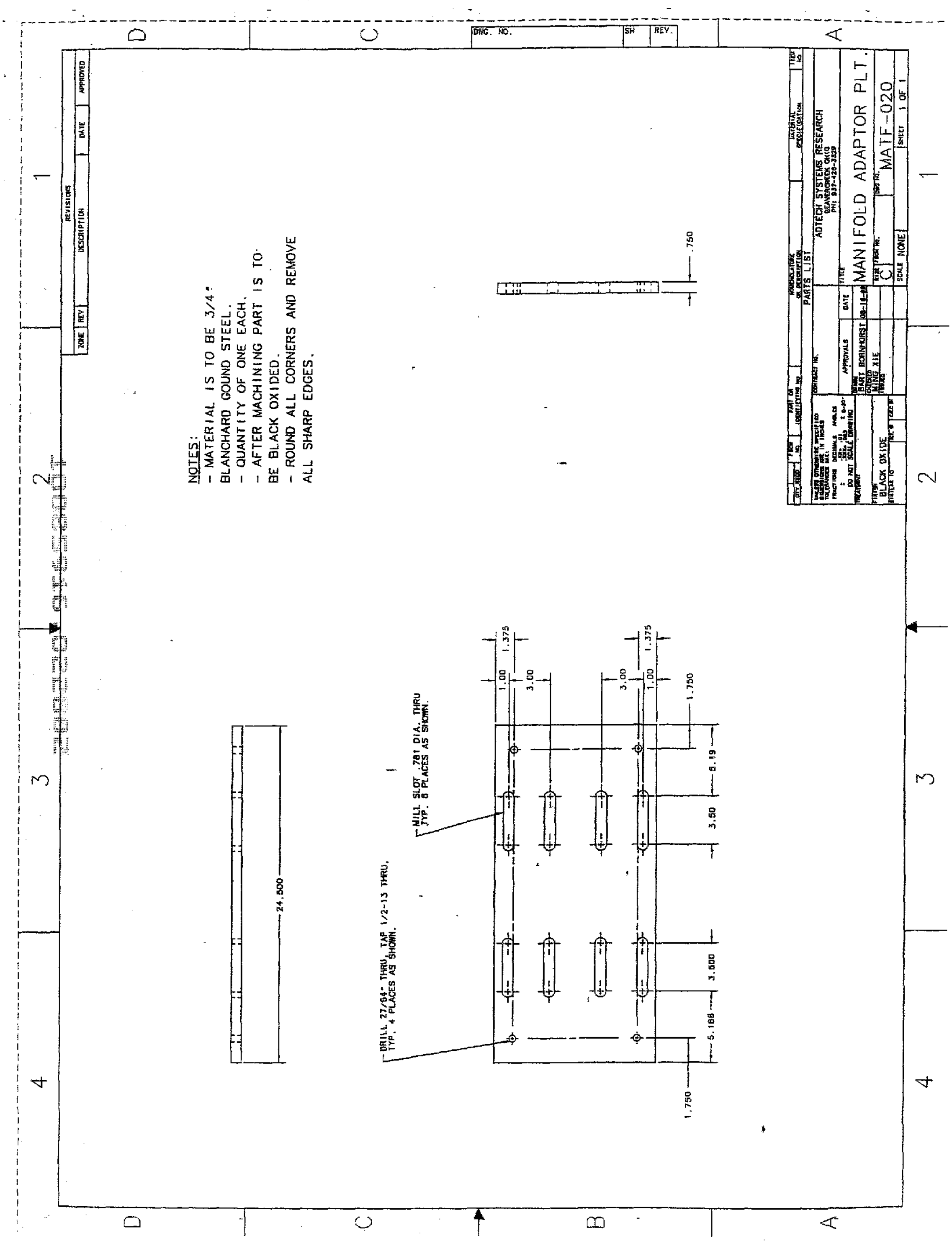

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
ADDED C/L NOTE
SLOT WIDTH FROM 2.208 TO 2.210
HALF SLOT WIDTH TO 1.105
ADDED 2 C/L NOTES
CHANGED RADIUS RELIEF SHAPE
CHANGED DWG. NUMBER
07-07-99
M. XIE
NOTES:
- MATERIAL IS TO BE COLD ROLLED STEEL.
- QUANTITY OF TWO EACH.
- AFTER MACHINING, ITEM IS TO RECEIVE A BLACK OXIDE TREATMENT.
- REMOVE ALL SHARP EDGES.
ISO VIEW
NOTE: FOR REF. ONLY
RIGHT SIDE VIEW
TOP VIEW
FRONT VIEW
PARTS LIST
ADTECH SYSTEMS RESEARCH
SMALL ACTUATOR FIXTURE
MATF-015-A
SCALE NONE
1 OF 1
BLACK OXIDE (SEE NOTE)
.125 RADIUS TYP. BOTH SIDES.
.25 RADIUS TYP. BOTH SIDES.
7.500
5.750
3.750
2.000
2.750
1.062
1.398
.500
.875
C/L

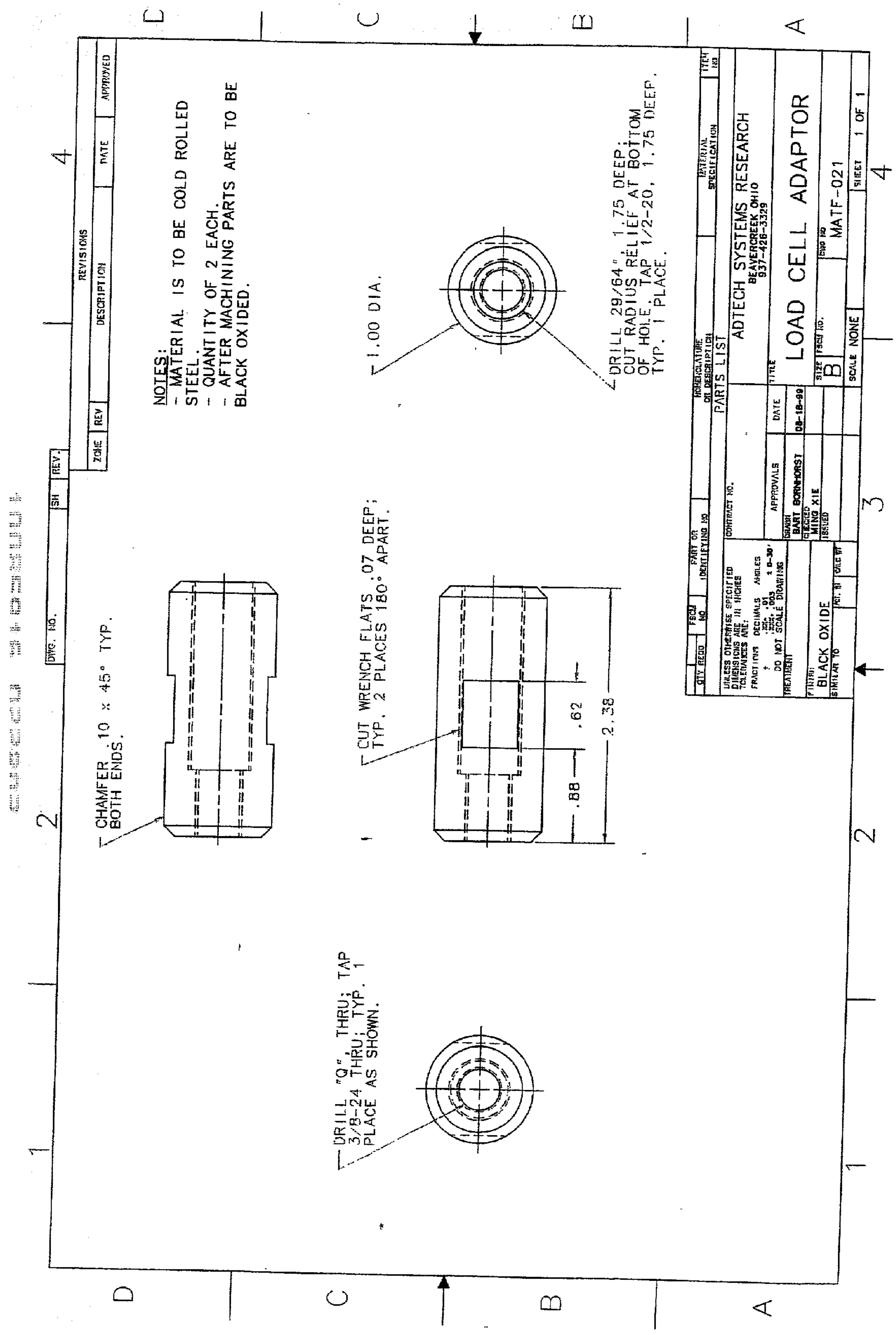

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
C-2
A
ADDED WRENCH FLATS
08-02-99
M. XIE
DWG. NO.
SH
REV.
NOTES:
- MATERIAL IS TO BE COLD ROLLED STEEL.
- QUANTITY OF 2 EACH.
- PART IS TO BE BLACK OXIDED.
- REMOVE ALL SHARP EDGES.
DRILL "Q", THRU; TAP 3/8-24 THRU, 1 PLACE ONLY.
LEFT SIDE VIEW
.05 RADIUS TYP. BOTH ENDS.
CUT WRENCH FLATS .10 DEEP, TYP. 2 PLACES 360 DEGREES APART.
1.500 DIA.
.750
C/L
1.12
3.00
.75
FRONT VIEW
BORE 15/16" DIA., 2.25 DEEP, CHASE A, 1-14 THREAD, 2.20 DEEP.
RIGHT SIDE VIEW
PARTS LIST
ADTECH SYSTEMS RESEARCH INC
BEAVERCREEK, OHIO
CALIBRATION ADAPTOR
B
MATF-016-A
SCALE NONE
SHEET 1 OF 1
BART BORNHORST
07-16-99
MING XIE
BLACK OXIDE (SEE NOTE)
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING

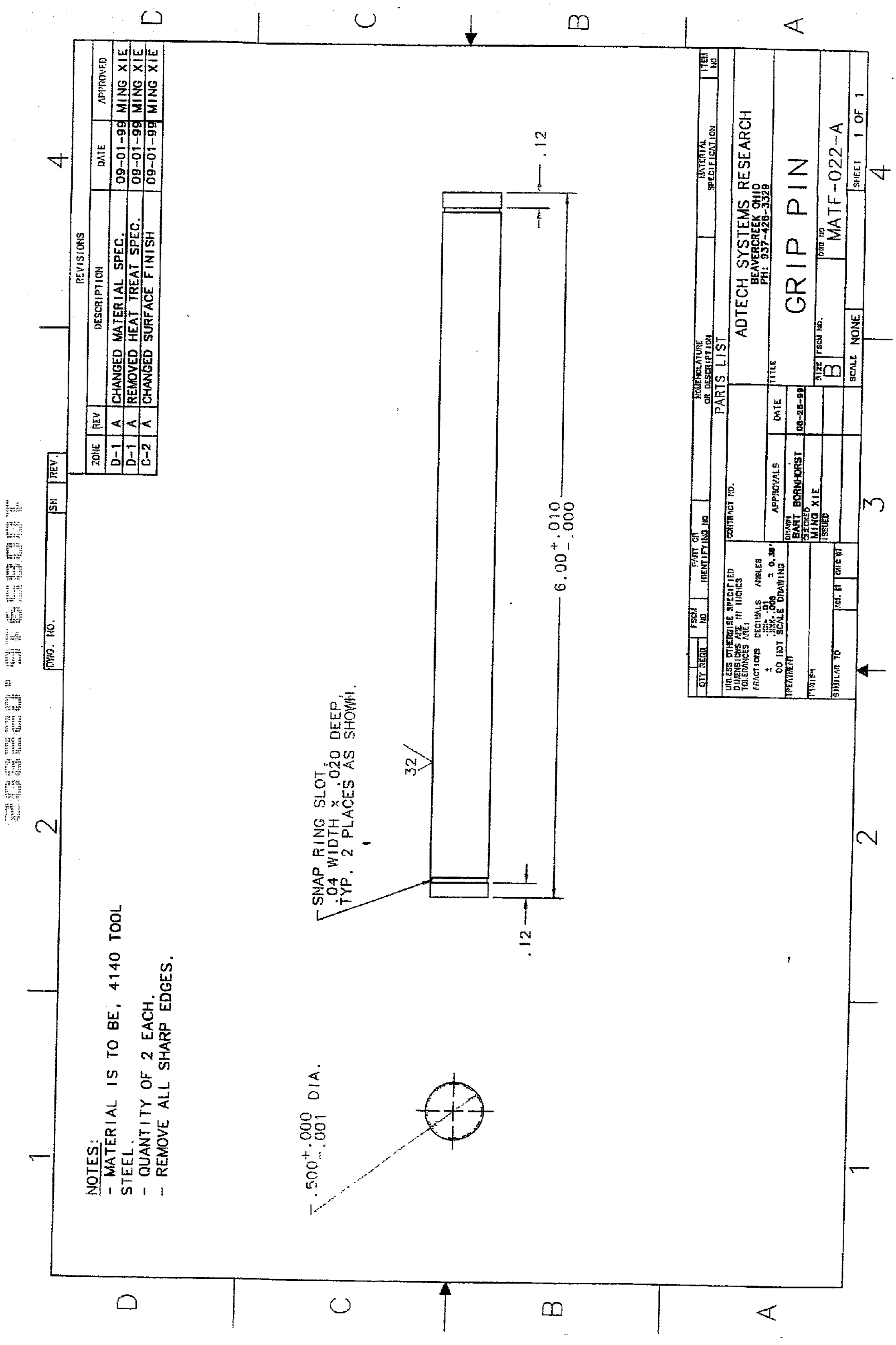

NOTES:
- MATERIAL IS TO BE COLD ROLLED STEEL.
- QUANTITY OF 2 EACH.
- REMOVE ALL SHARP EDGES.
- AFTER MACHINING PART IS TO BE BLACK OXIDED.
REVISIONS
ZONE REV DESCRIPTION DATE APPROVED
B-3 A CHANGED PLATE THICKNESS 08-02-99 M. XIE
RIGHT SIDE VIEW
1.00
TOP VIEW
FRONT VIEW
DRILL 15/16" THRU; TAP 1-14 THRU. TYP. 1 EACH.
MILL SLOT .5312 DIA. THRU, TYP 2 PLACES EACH.
4.00
2.625
1.312
C/L
2.000
6.00
ADTECH SYSTEMS RESEARCH INC.
BEAVERCREEK, OHIO
PH: 937-426-3329
CALIBRATION PLATE
MATF-017-A
PARTS LIST
DRAWN BART BORNHORST 07-16-99
CHECKED MING XIE 07-16-99
FINISH BLACK OXIDE (SEE NOTE)
SIZE B
SCALE NONE
SHEET 1 OF 1

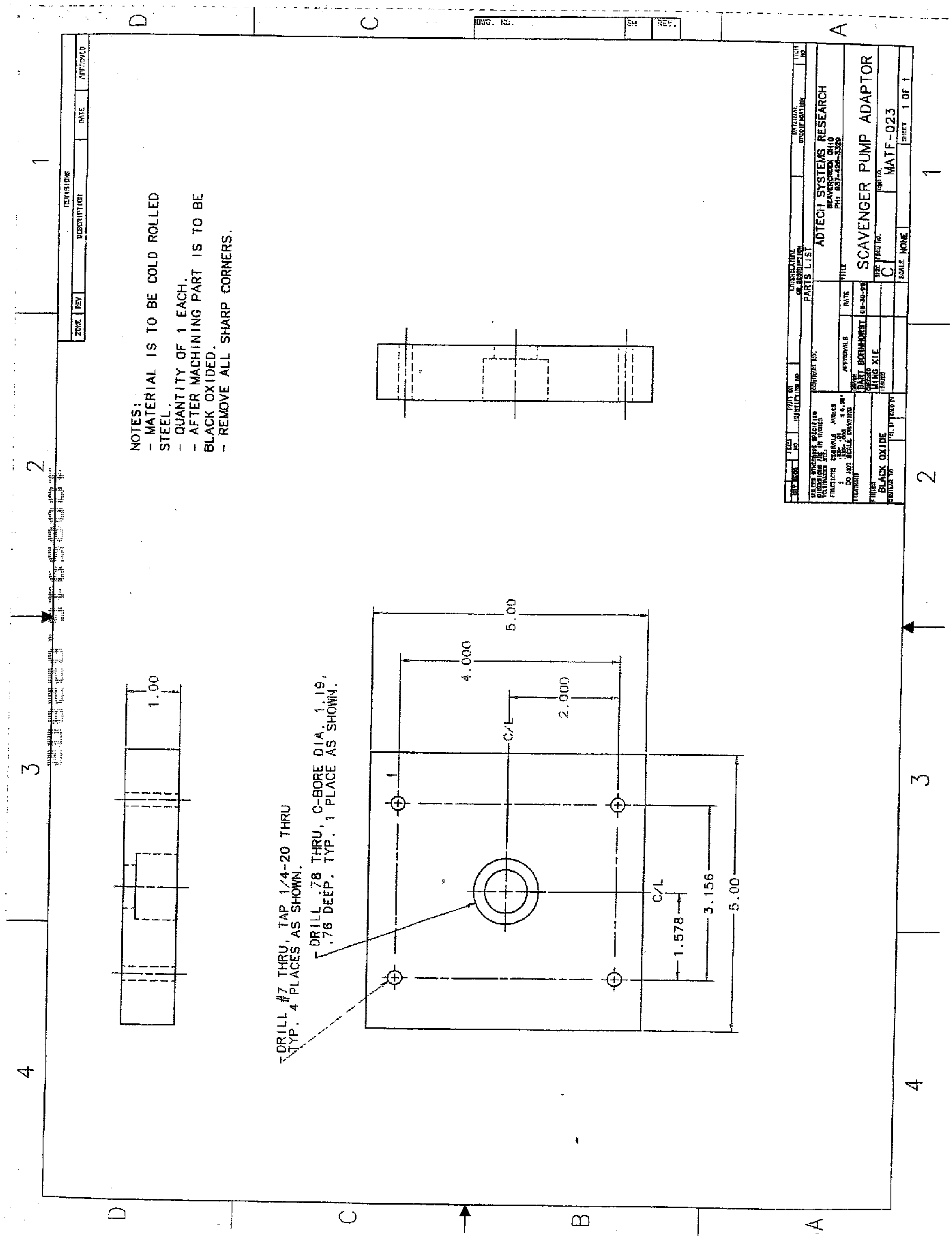

NOTES:
- MATERIAL IS TO BE COLD ROLLED STEEL.
- QUANTITY OF 2 EACH.
- PARTS ARE TO BE BLACK OXIDED.
- REMOVE ALL SHARP EDGES.
1.00" DIA.
LEFT SIDE VIEW
M12 THREAD
CUT RADIUS RELIEF .05 R.
CUT WRENCH FLAT .0625 DEEP TYP. 2 PLACES, SPACED 360 DEGREES APART.
ROUND BOTH ENDS .05 R.
.25
.50
1.00
.625
FRONT VIEW
DRILL "Q", .8125 DEEP, TAP 3/8-24, .75 DEEP; TYP. 1 PLACE ONLY.
RIGHT SIDE VIEW
ISO VIEW
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
PARTS LIST
LOAD CELL ADAPTOR
MATF-018
SIZE B
SCALE NONE
SHEET 1 OF 1
DRAWN BART BORNHORST 07-27-99
CHECKED MING XIE
APPROVALS
DATE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
TREATMENT
FINISH
SIMILAR TO
A
B
C
D
1
2
3
4

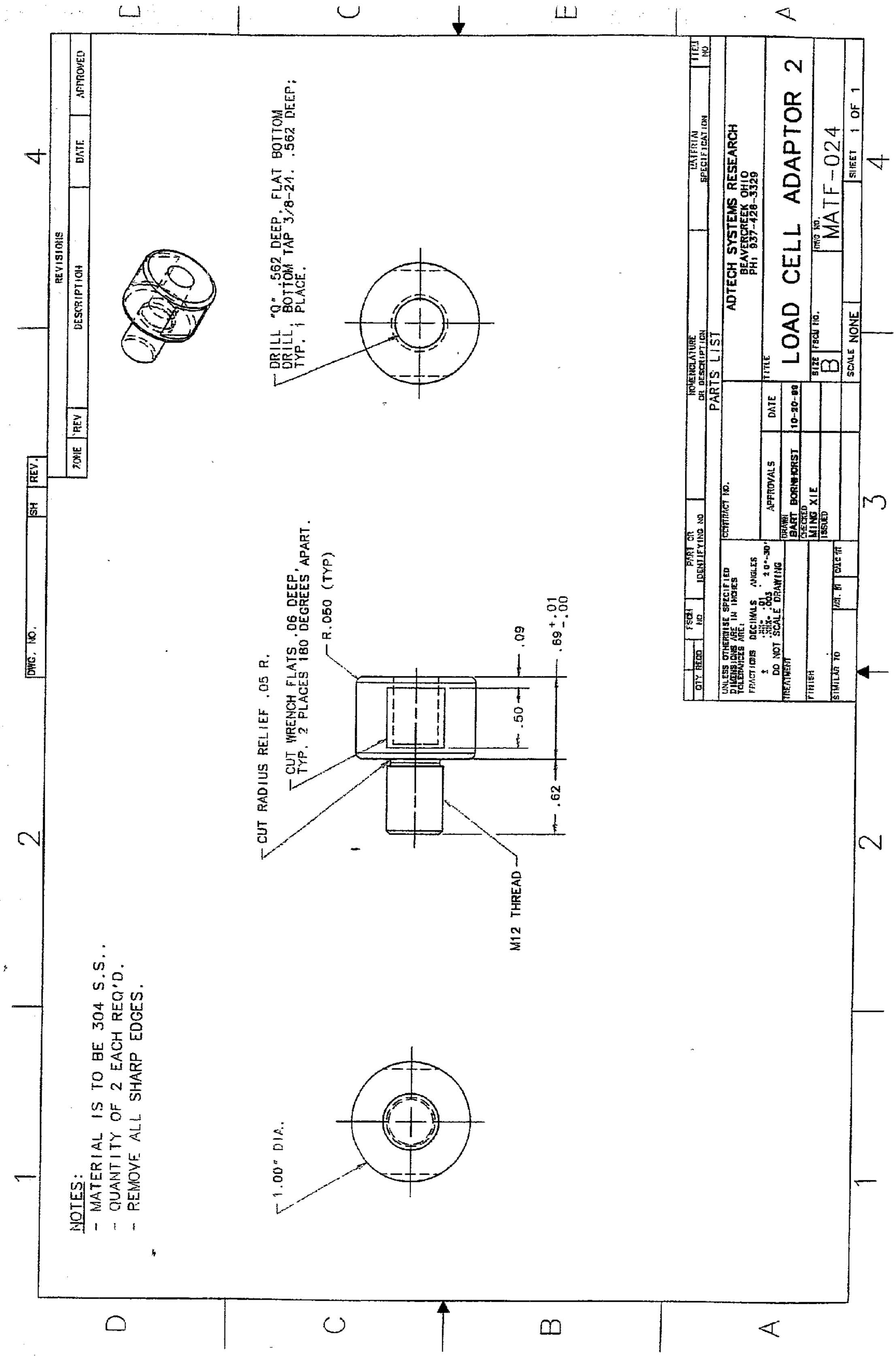

NOTES:
- SPIRAL WASHERS MATERIAL IS ALUMINUM. STEEL
- DRILL OUT CENTER HOLE DIA. AS SHOWN.
- QUANTITY OF 4 EACH.
- SPIRAL WASHERS ARE AN EXISTING ITEM.
TITLE: SPIRAL WASHER
DRAWN BY: BART BORDHORST
DATE: 08-02-99
DRAWING NO: MATF-019
ADTECH SYSTEMS RES.
BEAVERCREEK OH.
937-426-3329
.559
1.500 EXISTING DIA.
.03 x 45° CHAMFER
2.603 EXISTING DIA.
1.187 +.002 -.000 NEW DIA.
1.003 EXISTING DIA.

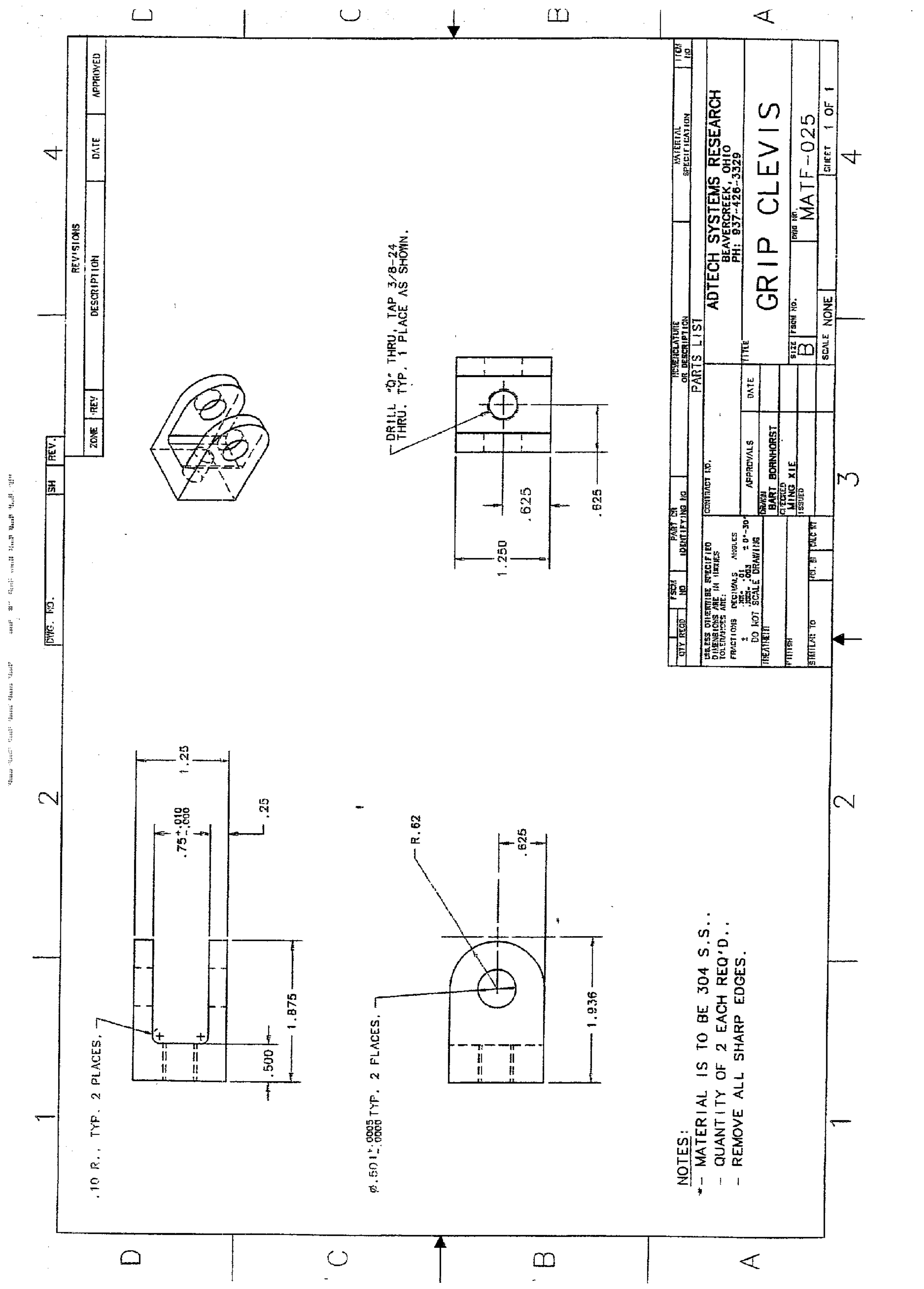

NOTES:
- MATERIAL IS TO BE 3/4" BLANCHARD GOUND STEEL.
- QUANTITY OF ONE EACH.
- AFTER MACHINING PART IS TO BE BLACK OXIDED.
- ROUND ALL CORNERS AND REMOVE ALL SHARP EDGES.
MILL SLOT .781 DIA. THRU TYP. 8 PLACES AS SHOWN.
DRILL 27/64" THRU, TAP 1/2-13 THRU. TYP. 4 PLACES AS SHOWN.
24.500
.750
1.750
3.500
5.188
5.19
3.50
1.375
1.00
3.00
REVISIONS
PARTS LIST
ADTECH SYSTEMS RESEARCH
BART BORNHORST
BLACK OXIDE
MANIFOLD ADAPTOR PLT.
MATF-020
SCALE NONE
SHEET 1 OF 1

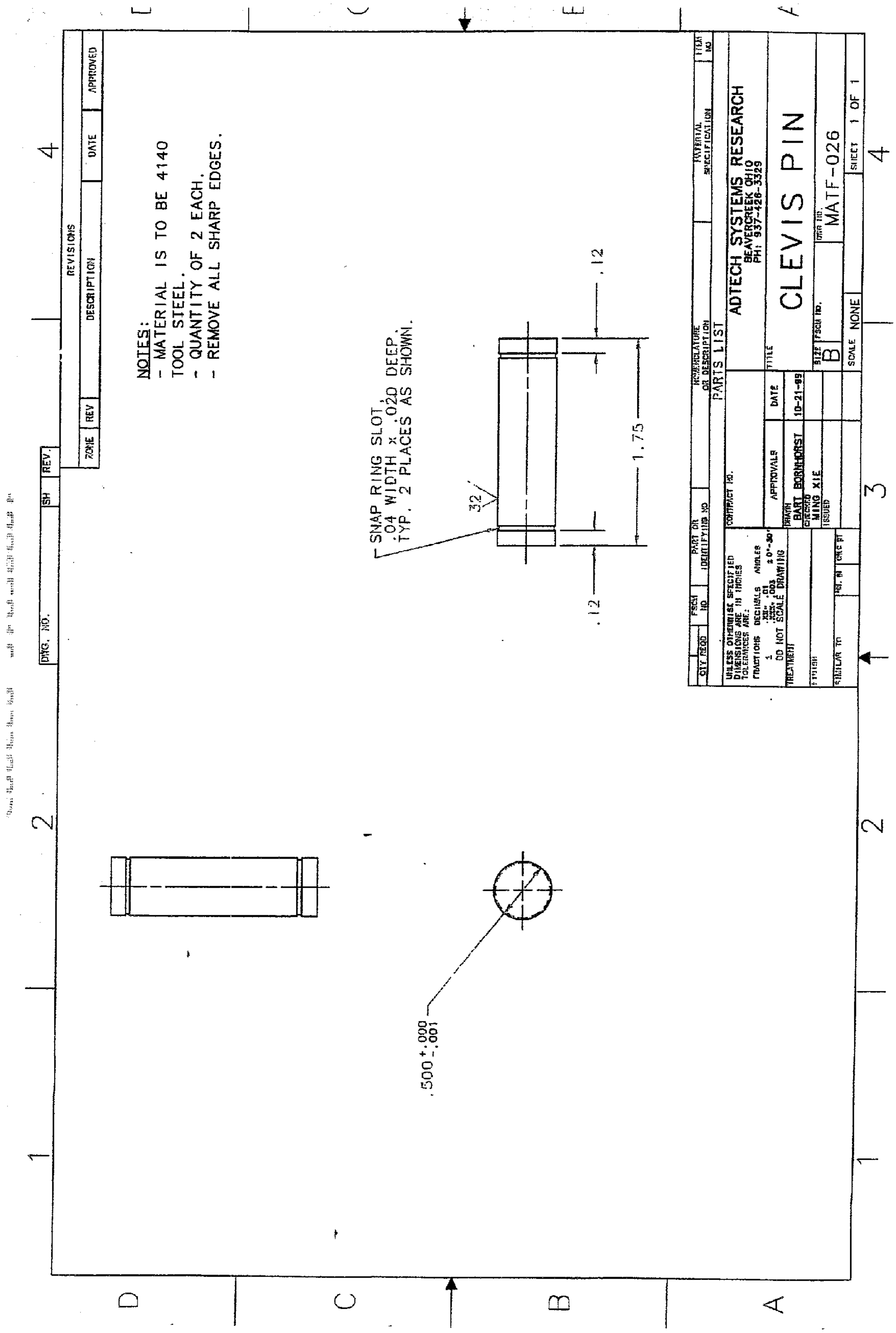

NOTES:
- MATERIAL IS TO BE COLD ROLLED STEEL.
- QUANTITY OF 2 EACH.
- AFTER MACHINING PARTS ARE TO BE BLACK OXIDED.
1.00 DIA.
DRILL 29/64", 1.75 DEEP; CUT RADIUS RELIEF AT BOTTOM OF HOLE. TAP 1/2-20, 1.75 DEEP. TYP. 1 PLACE.
CHAMFER .10 x 45° TYP. BOTH ENDS.
CUT WRENCH FLATS .07 DEEP; TYP. 2 PLACES 180° APART.
.62
.88
2.38
DRILL "Q", THRU; TAP 3/8-24 THRU; TYP. 1 PLACE AS SHOWN.
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
937-426-3329
LOAD CELL ADAPTOR
PARTS LIST
DRAWN BART BORNHORST
CHECKED MING XIE
08-18-99
BLACK OXIDE
SIZE B
DWG NO MATF-021
SCALE NONE
SHEET 1 OF 1

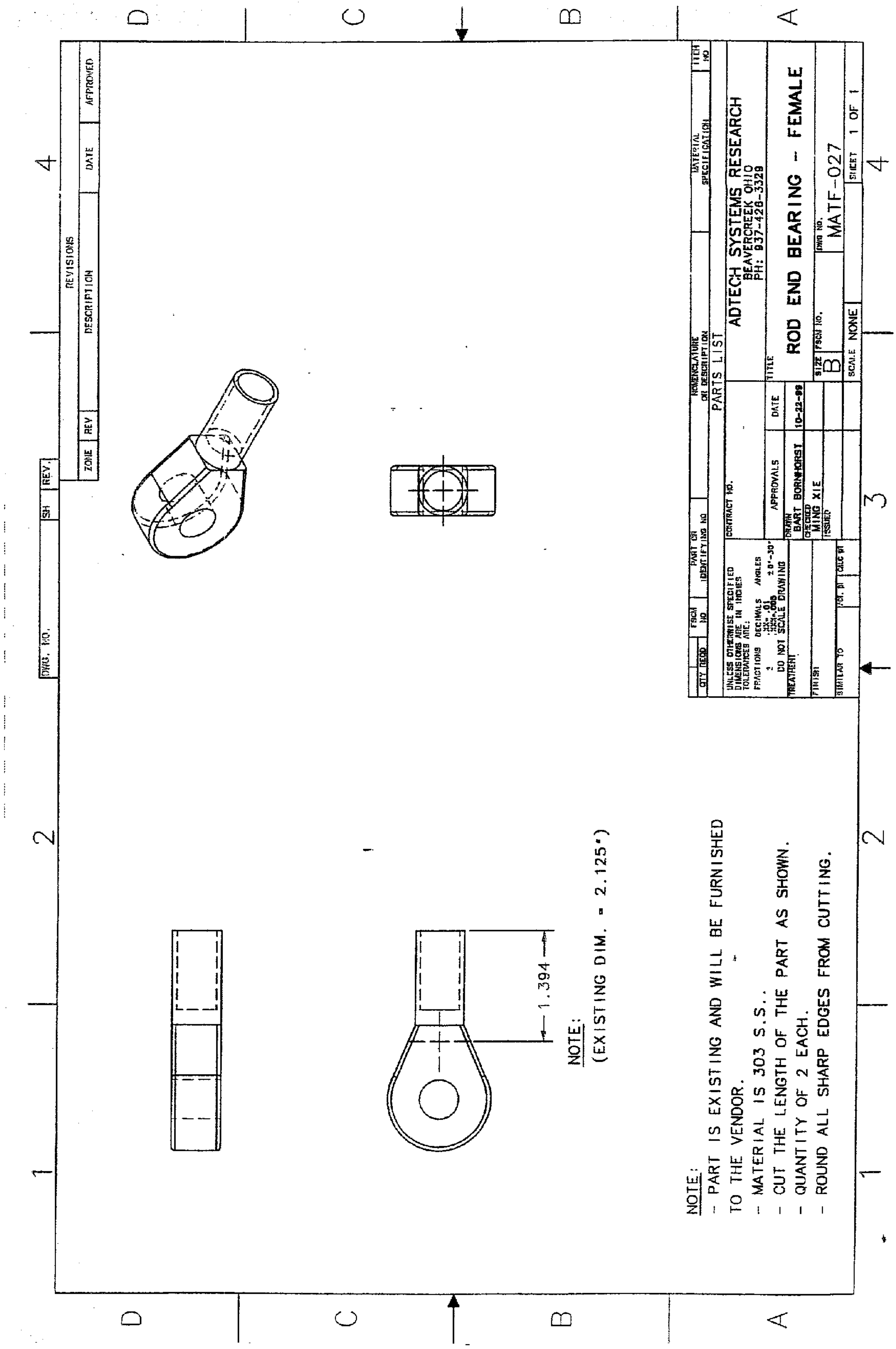

REVISIONS
ZONE REV DESCRIPTION DATE APPROVED
D-1 A CHANGED MATERIAL SPEC. 09-01-99 MING XIE
D-1 A REMOVED HEAT TREAT SPEC. 09-01-99 MING XIE
C-2 A CHANGED SURFACE FINISH 09-01-99 MING XIE
DWG. NO. SH REV.
NOTES:
- MATERIAL IS TO BE, 4140 TOOL STEEL.
- QUANTITY OF 2 EACH.
- REMOVE ALL SHARP EDGES.
.500 +.000 -.001 DIA.
SNAP RING SLOT, .04 WIDTH x .020 DEEP. TYP. 2 PLACES AS SHOWN.
32
.12
.12
6.00 +.010 -.000
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
GRIP PIN
MATF-022-A
SHEET 1 OF 1
SIZE B
SCALE NONE
DRAWN BART BORNHORST 08-25-99
CHECKED MING XIE
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING

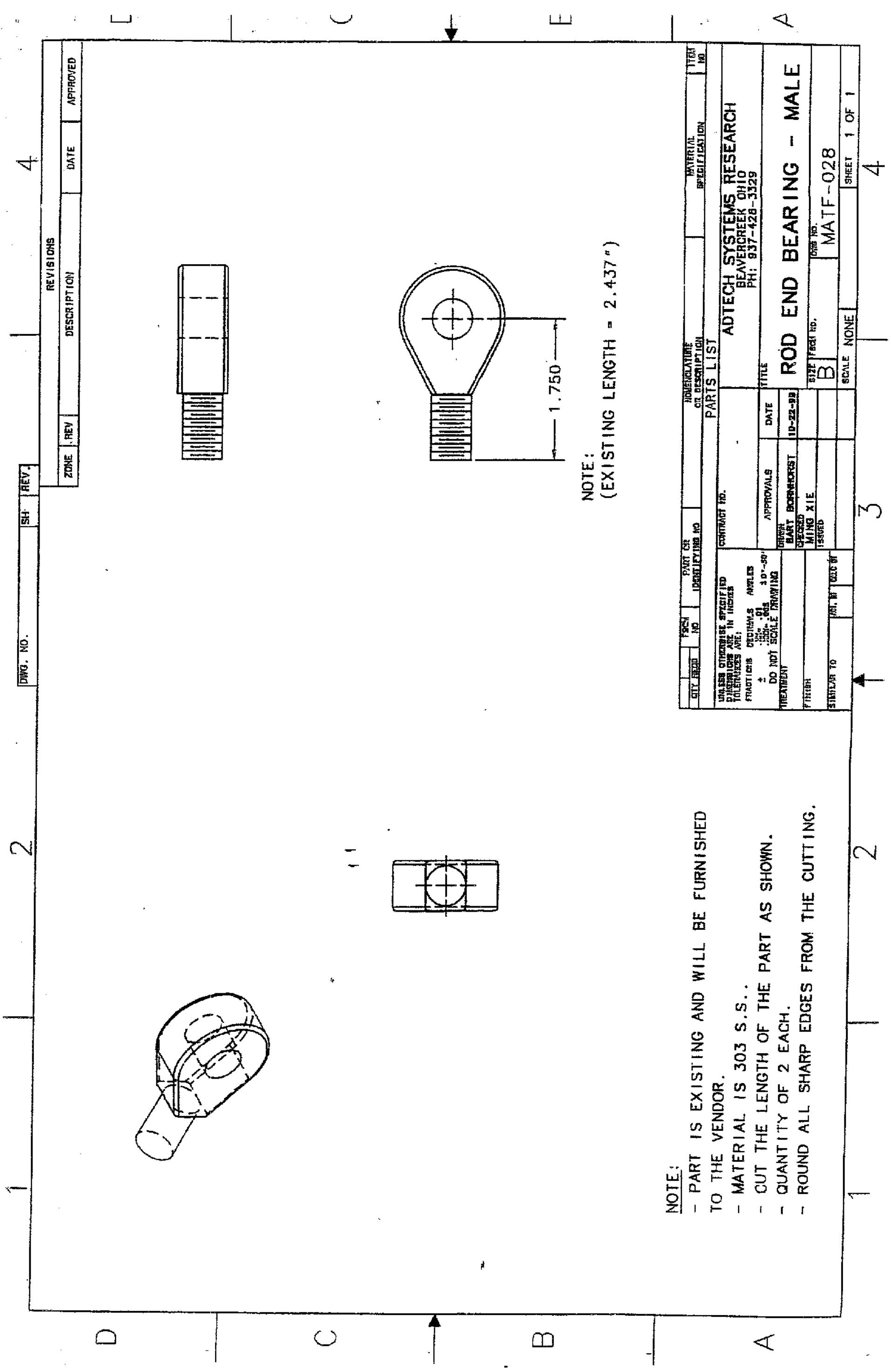

NOTES:
- MATERIAL IS TO BE COLD ROLLED STEEL.
- QUANTITY OF 1 EACH.
- AFTER MACHINING PART IS TO BE BLACK OXIDED.
- REMOVE ALL SHARP CORNERS.
DRILL #7 THRU, TAP 1/4-20 THRU TYP. 4 PLACES AS SHOWN.
DRILL .78 THRU, C-BORE DIA. 1.19, .76 DEEP. TYP. 1 PLACE AS SHOWN.
5.00
4.000
2.000
C/L
3.156
1.578
1.00
ADTECH SYSTEMS RESEARCH
SCAVENGER PUMP ADAPTOR
MATF-023
BLACK OXIDE
SCALE NONE
SHEET 1 OF 1
PARTS LIST

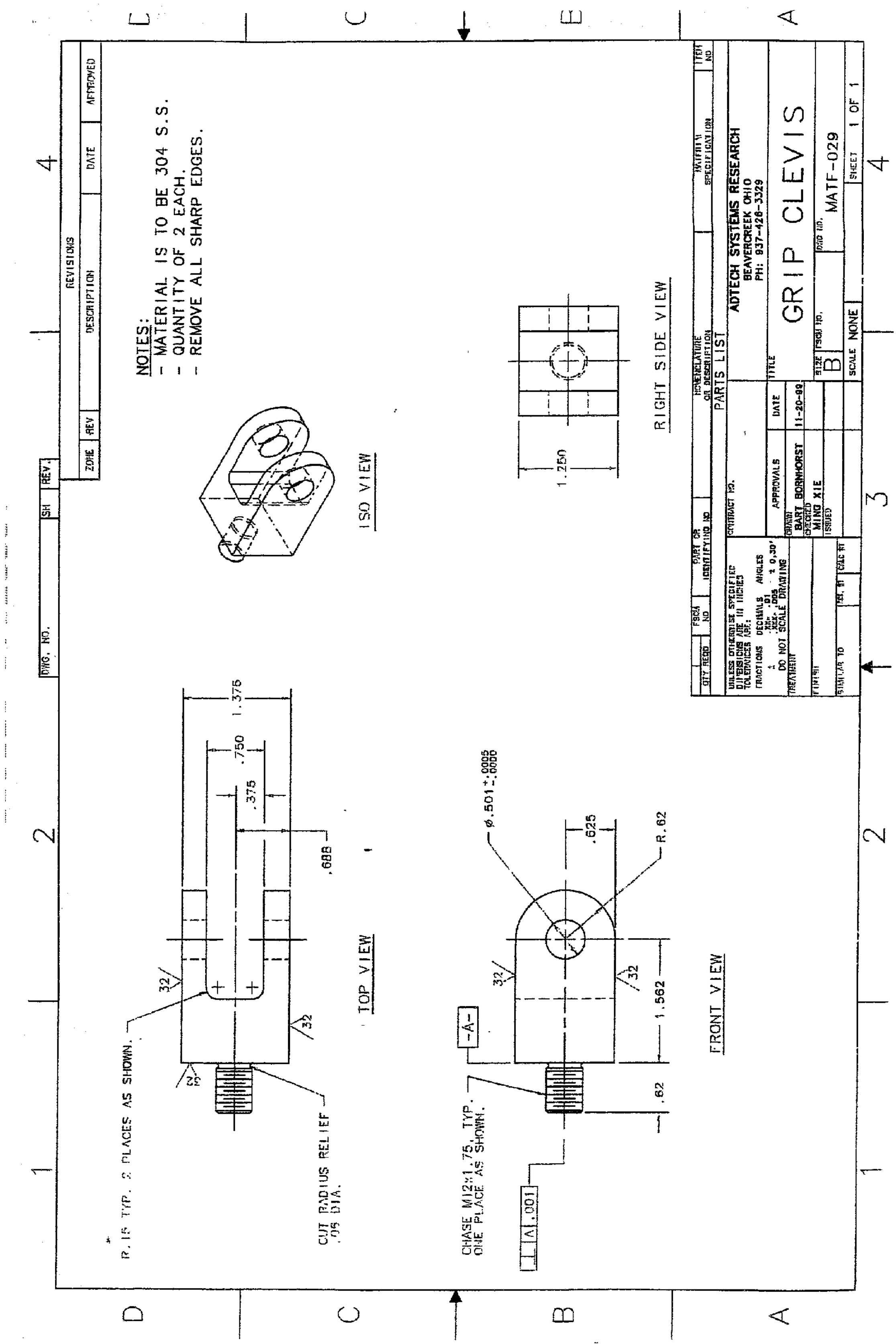

NOTES:
- MATERIAL IS TO BE 304 S.S..
- QUANTITY OF 2 EACH REQ'D.
- REMOVE ALL SHARP EDGES.
1.00" DIA.
CUT RADIUS RELIEF .05 R.
CUT WRENCH FLATS .06 DEEP, TYP. 2 PLACES 180 DEGREES APART.
R.050 (TYP)
.09
.50
.62
.69 +.01 -.00
M12 THREAD
DRILL "Q" .562 DEEP, FLAT BOTTOM
DRILL, BOTTOM TAP 3/8-24. .562 DEEP;
TYP. 1 PLACE.
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
LOAD CELL ADAPTOR 2
APPROVALS
DATE
DRAWN
BART BORNHORST
10-20-99
CHECKED
MING XIE
ISSUED
SIZE
B
DWG NO.
MATF-024
SCALE NONE
SHEET 1 OF 1
DO NOT SCALE DRAWING
TREATMENT
FINISH
SIMILAR TO

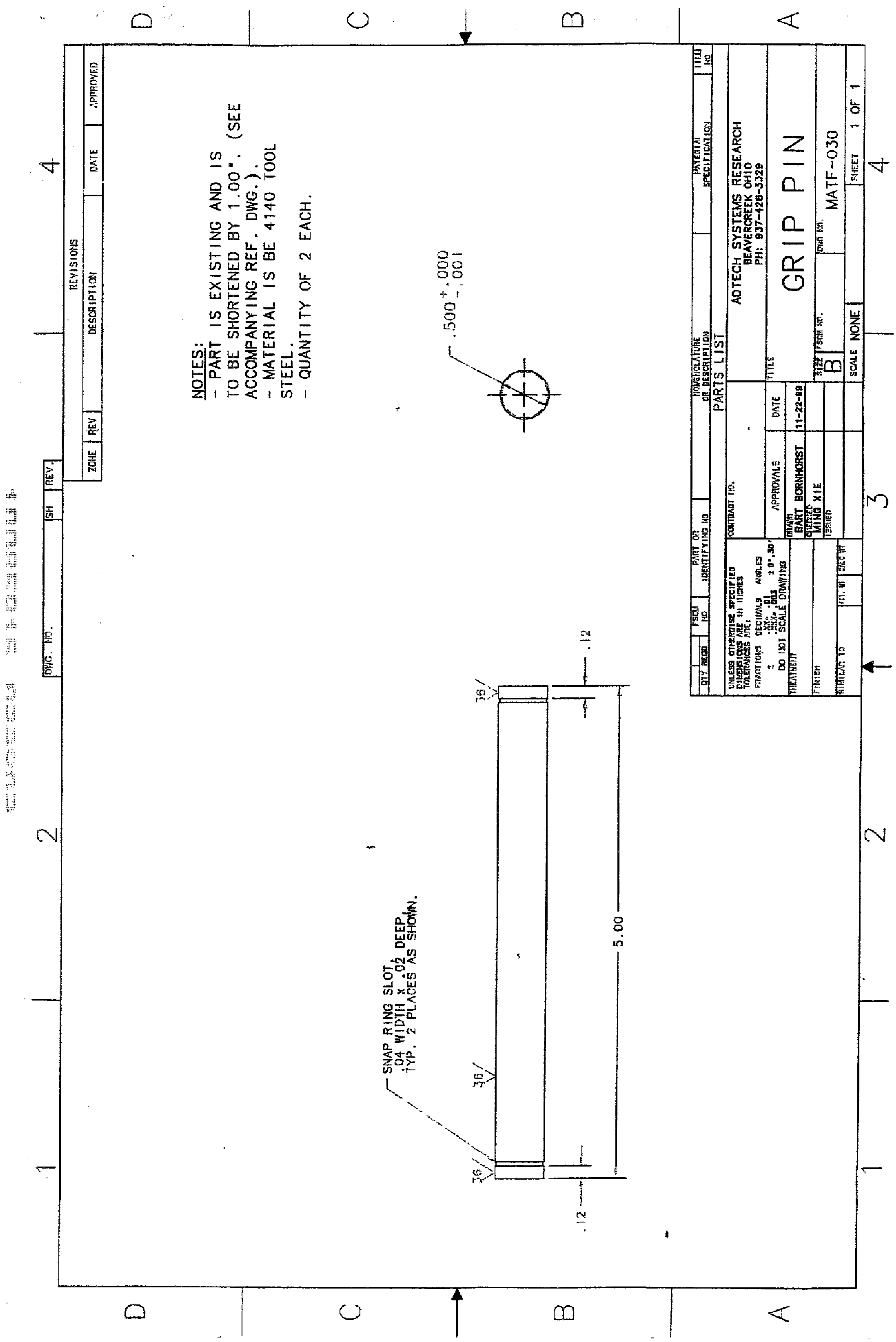

REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
DRILL "Q" THRU, TAP 3/8-24 THRU. TYP. 1 PLACE AS SHOWN.
.625
.625
1.250
.10 R., TYP. 2 PLACES.
1.25
.75+.010 -.000
.25
1.875
.500
R.62
.625
1.936
ø.501+.0005 -.0000 TYP. 2 PLACES.
NOTES:
- MATERIAL IS TO BE 304 S.S..
- QUANTITY OF 2 EACH REQ'D..
- REMOVE ALL SHARP EDGES.
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK, OHIO
PH: 937-426-3329
GRIP CLEVIS
MATF-025
SCALE NONE
SHEET 1 OF 1
DRAWN BART BORNHORST
CHECKED MING XIE
APPROVALS
DATE
DO NOT SCALE DRAWING

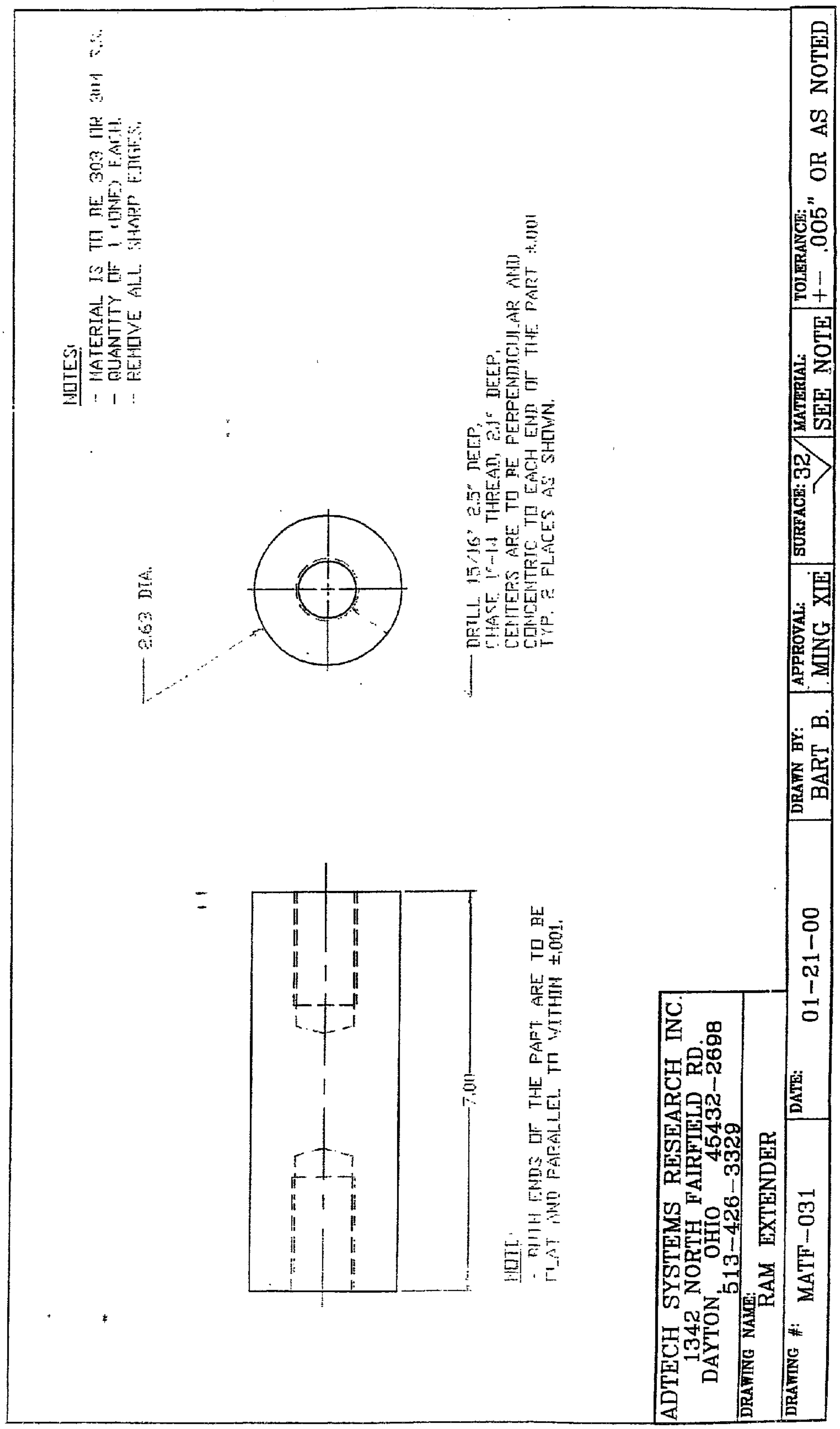

NOTES:
- MATERIAL IS TO BE 4140 TOOL STEEL.
- QUANTITY OF 2 EACH.
- REMOVE ALL SHARP EDGES.
SNAP RING SLOT, .04 WIDTH x .020 DEEP. TYP. 2 PLACES AS SHOWN.
32
.12
1.75
.12
.500 +.000 -.001
REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
CLEVIS PIN
MATF-026
SCALE NONE
SHEET 1 OF 1
DRAWN BART BORNHORST
CHECKED MING XIE
10-21-99
DO NOT SCALE DRAWING


REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
1.394
NOTE:
(EXISTING DIM. = 2.125")
NOTE:
- PART IS EXISTING AND WILL BE FURNISHED TO THE VENDOR.
- MATERIAL IS 303 S.S..
- CUT THE LENGTH OF THE PART AS SHOWN.
- QUANTITY OF 2 EACH.
- ROUND ALL SHARP EDGES FROM CUTTING.
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
ROD END BEARING - FEMALE
DRAWN BART BORNHORST
CHECKED MING XIE
DATE 10-22-99
SIZE B
DWG NO. MATF-027
SCALE NONE
SHEET 1 OF 1


REVISIONS
ZONE
REV
DESCRIPTION
DATE
APPROVED
DWG. NO.
SH
REV.
NOTE:
(EXISTING LENGTH = 2.437")
1.750
NOTE:
- PART IS EXISTING AND WILL BE FURNISHED TO THE VENDOR.
- MATERIAL IS 303 S.S..
- CUT THE LENGTH OF THE PART AS SHOWN.
- QUANTITY OF 2 EACH.
- ROUND ALL SHARP EDGES FROM THE CUTTING.
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
DO NOT SCALE DRAWING
APPROVALS
DATE
DRAWN BART BORNHORST 10-22-99
CHECKED MING XIE
TREATMENT
FINISH
TITLE
ROD END BEARING - MALE
SIZE B
DWG NO. MATF-028
SCALE NONE
SHEET 1 OF 1


NOTES:
- MATERIAL IS TO BE 304 S.S.
- QUANTITY OF 2 EACH.
- REMOVE ALL SHARP EDGES.
ISO VIEW
RIGHT SIDE VIEW
TOP VIEW
FRONT VIEW
PARTS LIST
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
GRIP CLEVIS
MATF-029
BART BORNHORST
MING XIE
11-20-99
SCALE NONE
SHEET 1 OF 1
R.62
.625
1.562
.62
1.250
1.375
.750
.375
.688
CUT RADIUS RELIEF
R.15 TYP. 2 PLACES AS SHOWN.
REVISIONS


NOTES:
- PART IS EXISTING AND IS TO BE SHORTENED BY 1.00". (SEE ACCOMPANYING REF. DWG.).
- MATERIAL IS BE 4140 TOOL STEEL.
- QUANTITY OF 2 EACH.
.500 +.000 -.001
SNAP RING SLOT, .04 WIDTH x .02 DEEP, TYP. 2 PLACES AS SHOWN.
5.00
.12
ADTECH SYSTEMS RESEARCH
BEAVERCREEK OHIO
PH: 937-426-3329
GRIP PIN
MATF-030
PARTS LIST
BART BORNHORST
MING XIE
11-22-99
SCALE NONE
SHEET 1 OF 1
REVISIONS


NOTES:
- MATERIAL IS TO BE 303 OR 304 S.S.
- QUANTITY OF 1 (ONE) EACH.
- REMOVE ALL SHARP EDGES.
2.63 DIA.
DRILL 15/16" 2.5" DEEP,
CHASE 1"-14 THREAD, 2.1" DEEP.
CENTERS ARE TO BE PERPENDICULAR AND
CONCENTRIC TO EACH END OF THE PART ±.001
TYP. 2 PLACES AS SHOWN.
7.00
NOTE:
- BOTH ENDS OF THE PART ARE TO BE
FLAT AND PARALLEL TO WITHIN ±.001.
ADTECH SYSTEMS RESEARCH INC.
1342 NORTH FAIRFIELD RD.
DAYTON, OHIO 45432-2698
513-426-3329
DRAWING NAME:
RAM EXTENDER
DRAWING #: MATF-031
DATE: 01-21-00
DRAWN BY: BART B.
APPROVAL: MING XIE
SURFACE: 32
MATERIAL: SEE NOTE
TOLERANCE: +- .005" OR AS NOTED

APPENDIX C

Script for the Multi-axial High Frequency Test System Video

Scene 1 – AdTech logo.

Scene 2 – Title : "A Multi-axial High Frequency Test System."

Scene 3 – Graphics, excerpt from Phase I video (a turbine engine disk/blade assembly)

Narrator: In a typical turbine engine, rotating blades are subjected to both the centrifugal force and the periodic transverse excitation. This is a multi-axial loading condition also present during operation of many other high performance mechanical systems.

Scene 4 – Excerpt from Phase I video (prototype biaxial machine)

Narrator: In 1998, AdTech Systems Research Incorporated of Dayton, Ohio successfully developed a prototype biaxial loading test system. This four-post test frame is capable of applying mechanical loading on perpendicular axes through two servo hydraulic actuators. Its purpose was to demonstrate the feasibility of performing multi-axial loading simulation tests on turbine engine components.

Scene 5 – Computer and operator, zoom in to computer screen (finite element model)

Narrator: After the "proof of concept" demonstration of the prototype test frame, AdTech Systems Research continued to develop the multi-axial loading test methodology for advanced materials and structures, including high cycle fatigue testing of turbine engine blades.

Scene 6 – Graphics (bending and torsion modes of a deformed blade)

Narrator: Since vibration of turbine engine blades under service conditions includes bending and torsion modes, two actuators have been designed into the test system to simulate the combined bending and torsional vibration loading.

Scene 7 – Animation (two horizontal actuators are moving)

Narrator: When they move in-phase, the blade is subjected to torsion loading. When they move out-of-phase, the blade is subjected to bending loading.

Scene 8 – Animation (test frame, three actuators are being mounted)

Narrator: The new test frame design has three servo hydraulic actuators. Two movable small actuators, capable of high frequency loading, are mounted on the sidewall of the frame, and the main actuator is mounted on the bottom of the frame.

Scene 9 – Overview of the machine

Narrator: In September 1999, AdTech Systems Research completed design and manufacture, and installed the multi-axial test frame in the Air Force Research Laboratory's Turbine Engine Fatigue Facility at Wright-Patterson Air Force Base.

Scene 10 – Zoom in to the vibrating blade and gripping

Narrator: Multi-axial high cycle fatigue testing is being performed on a General Electric F110 turbine engine second stage fan blade. Two movable side actuators can apply a transverse fatigue loading to the blade. At the same time, the main actuator can apply a radial loading to the airfoil to simulate the centrifugal force.

Scene 11 – Control system, computer and the operator

Narrator: A digital three-station control system controls all three actuators, monitoring the load and displacement conditions while performing high-speed data acquisition. Two side actuators on the test frame, with 1000-pound capacity each, can apply high frequency loading up to 400 Hz, while the main actuator has an 11,000-pound loading capacity.

Scene 12 – Overview of the machine, then zoom in to one side actuator

Narrator: The test system can be used to test many other engineering structures under multi-axial high frequency loading. Two side actuators are movable and can apply loads to different locations of the test specimen.

Scene 13 – Computer screen shot (control software)

Narrator: The user-friendly control software makes it easy to setup and operate the test system. Three servo hydraulic actuators can be controlled individually or as a group.

Scene 14 – Computer screen, then overview of the machine

Narrator: This test system can be used in the design, development and analysis of operational gas turbine engine components, as well as evaluation of other advanced materials and structures. All currently available commercial test frames have only uniaxial loading capability. This multi-axial test system offers many new capabilities and will have important applications in both the research community and industry.

Scene 15 – Credits and acknowledgment (no narration)

Principal Engineer and Program Manager – Ming Xie, Ph.D.
Team Members – Bart Bornhorst, Mohan Balan and Norman Frey (consultant)

The development of the multi-axial high frequency test system was sponsored by the Turbine Engine Division of the Air Force Research Laboratory's Propulsion Directorate at the Wright-Patterson Air Force Base, Dayton, Ohio.

Air Force Technical Monitors and Support – Gary Terborg, Bruce Tavner and Charles Cross, Ph.D.

Scene 16 – AdTech logo

What is claimed is:

1. A multiaxial high cycle fatigue test system for testing bending, torsion, and tension of a gas turbine fan blade, comprising the following subsystems:

(1) a main test frame support, including an enclosed chamber with four side walls;

(2) a main test frame support, including two I-beam pedestals reinforced by gussets;

(3) an auxiliary test frame support, including a four-post die set and other mounting adapters;

(4) servo-hydraulic components, including a hydraulic service manifold, two small high frequency actuators along a horizontal axis, and one large main actuator along a vertical axis;

(5) a multiaxial digital control and data acquisition system, including a control console and a computer work station;

wherein the large vertical actuator is used to apply a radial centrifugal force, and the two small horizontal actuators are used to apply vibratory loading; the two small side actuators being offset independently of each other, to enable the machine to apply both bending loads and torque to the blade;

the blade being subjected to torsion loading when the traverse actuators move in phase, that is when both actuators move either in or out at the same time, and the blade being subjected to bending loading when the actuators move out-of-phase, that is one actuator moves in when the other moves out or vice-versa.

2. A multiaxial high cycle fatigue test system according to claim 1, further including a gripping system to apply the multiaxial loading to the blade;

a broach block, wherein a dovetail of the blade slides into a dovetail of the broach block, and the blade is tightened against the block by two screws from underneath;

an adapter added to the base of the broach block, the adapter being connected to the stationary die plate by a threaded rod, the broach block being located on the adapter plate by two dowel pins, and attached to the adapter plate by four bolts, which facilitates the easy assembly and removal of the broach block and the blade for each test, wherein the dowel pins ensure that the broach block is returned to the same position as before it was removed from the machine, which eliminates the need for setting up the broach block between tests on same or similar blades;

a strap which is gripped by a hydraulic wedge grip, the hydraulic grip being mounted on the bottom (movable) die plate attached to the vertical actuator, the broach block and the specimen are mounted on the top (fixed) die plate, which ensures that the relative distance between the specimen and the transverse actuators remains undisturbed by the movements of the vertical actuator, and which also enables quick change over from one test to another on same or similar blades, by eliminating changes in the critical locating dimensions.

3. A multiaxial high cycle fatigue test system according to claim 2, wherein the two high frequency actuators provide 1.1 kip in the range of 0-400 Hz, and the main actuator operates at 11 kip;

wherein the system further includes a load cell of 2000 pound capacity mounted on the piston rod of each transverse actuator using an adapter, a clevis being attached to the load cell, the clevis being connected to the grip pin using two rod end bearings, wherein the grip pin extends from one end of the grip to the other end, wherein when the piston rod of a lateral actuator moves forward, it pushes one end of the grip pin forward via the clevis and the rod end bearings, which results in the application of a force to the specimen in the direction of the actuator movement, and wherein the rod end bearings and the clevis joints allow movement of the grip in the vertical direction to a certain extent.

4. A multiaxial high cycle fatigue test system for testing bending, torsion, and tension of a test unit, comprising:

servo-hydraulic components, including a hydraulic service manifold, two small high frequency actuators along a first axis, and one large main actuator along a second axis;

wherein the large main actuator is used to apply a radial centrifugal force, and the two small actuators are used to apply vibratory loading; the two small side actuators being offset independently of each other, to enable the machine to apply both bending loads and torque to the test unit;

the test unit being subjected to torsion loading when the traverse actuators move in phase, that is when both actuators move either in or out at the same time, and the test unit being subjected to bending loading when the actuators move out-of-phase, that is one actuator moves in when the other moves out or vice-versa.

5. A multiaxial high cycle fatigue test system according to claim 4, wherein the test unit is a component or a material sample.

6. A multiaxial high cycle fatigue test system according to claim 4, further including a gripping system to apply the multiaxial loading to the test unit;

a broach block having an adapter connected to a stationary die plate to facilitate easy assembly and removal of the broach block and the test unit for each test, wherein dowel pins ensure that the broach block is returned to the same position as before it was removed from the machine, which eliminates the need for setting up the broach block between tests on same or similar blades.

7. A multiaxial high cycle fatigue test system according to claim 6, further including a strap which is gripped by a hydraulic wedge grip, the hydraulic grip being mounted on the bottom (movable) die plate attached to the vertical actuator, wherein the broach block and the specimen are mounted on the top (fixed) die plate, which ensures that the relative distance between the specimen and the transverse actuators remains undisturbed by the movements of the vertical actuator, and which also enables quick change over from one test to another on same or similar blades, by eliminating changes in the critical locating dimensions.

8. A method of testing a test unit for bending, torsion, and tension, comprising:

using servo-hydraulic components, including a hydraulic service manifold, two small high frequency actuators along a first axis, and one large main actuator along a second axis;

using the large main actuator to apply a radial centrifugal force, and using the two small actuators are to apply vibratory loading; the two small side actuators being offset independently of each other, to enable the machine to apply both bending loads and torque to the test unit;

subjecting the test unit to torsion loading when the traverse actuators move in phase, that is when both actuators move either in or out at the same time, and subjecting the test unit to bending loading when the actuators move out-of-phase, that is one actuator moves in when the other moves out or vice-versa.

9. A method according to claim 8, wherein the test unit is turbine blade.

* * * * *