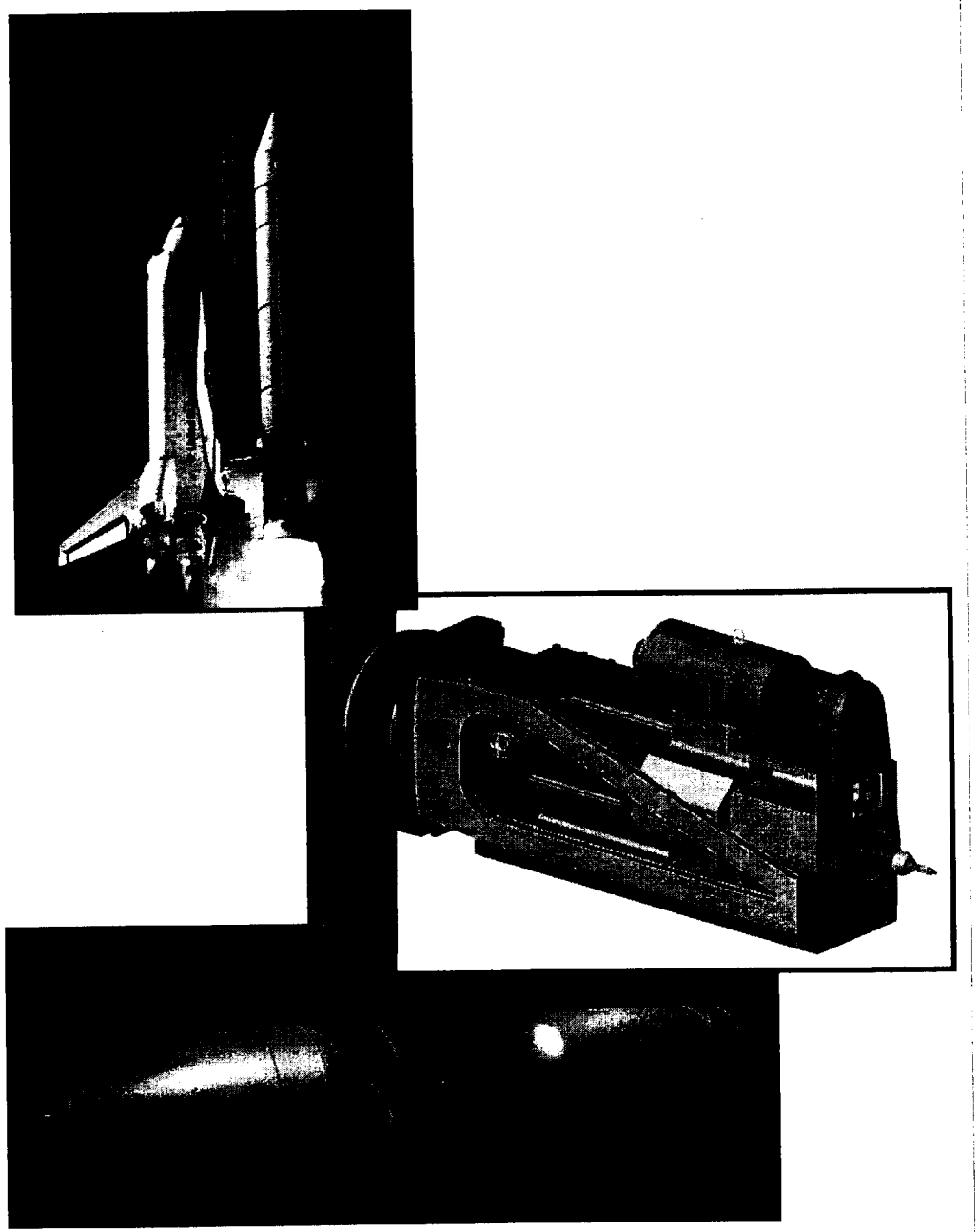
Friction Stir Welding on the External Tank

FSW of the Space Shuttle External Tank Longitudinal Barrel Welds



AEROMAT 2001
June 11-14, 2001

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Jack Thompson, Kirby Lawless

Friction Stir Welding on the External Tank

Friction Stir Welding - Presentation Overview

- *Project Objectives*
- *Tool Design*
- *Force Balance System*
- *Adjustable Pin Tool Mechanism*
- *Pin Measurement System*
- *Seam Tracking, Joint Gap and Thickness Offset*
- *Control System*
- *Implementation Status*

Friction Stir Welding on the External Tank

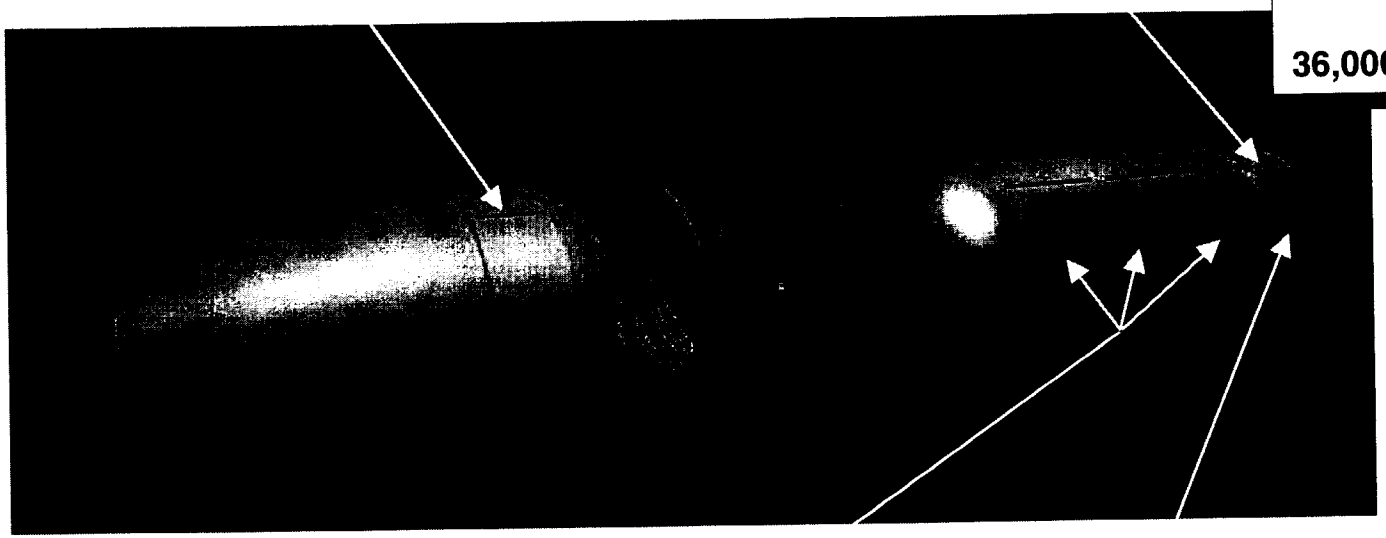
Objective

Increase the Safety, Reliability, & Producibility of the ET by Implementing the FSW Process

LO2 Barrel Welds
4 Each 8 -Feet Long
Tapered Thickness

LH2 Barrel 1 (Longeron Welds)
4 Each 15-feet Long
Tapered Thickness

Barrel Welds
8,000 Inches
Out of
36,000 Total Inches

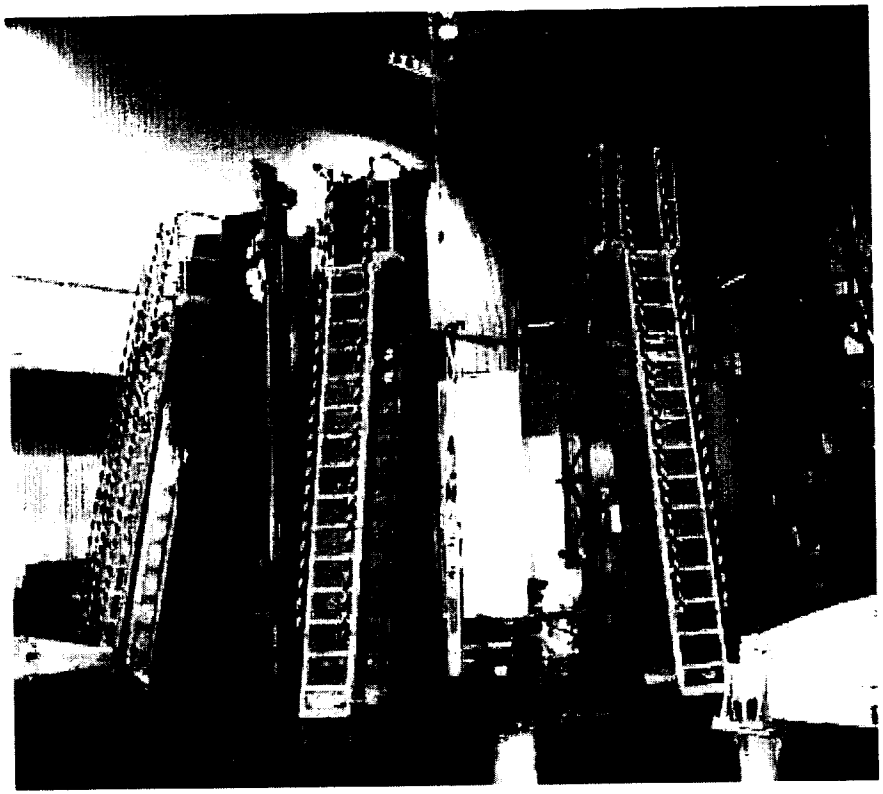


LH2 Barrels 2, 3 and 4 Welds
24 Each 20-feet Long
22 Each Constant Thickness
2 Each Tapered Thickness

LH2 Barrel 1 Welds
6 Each 15-feet Long
Constant Thickness

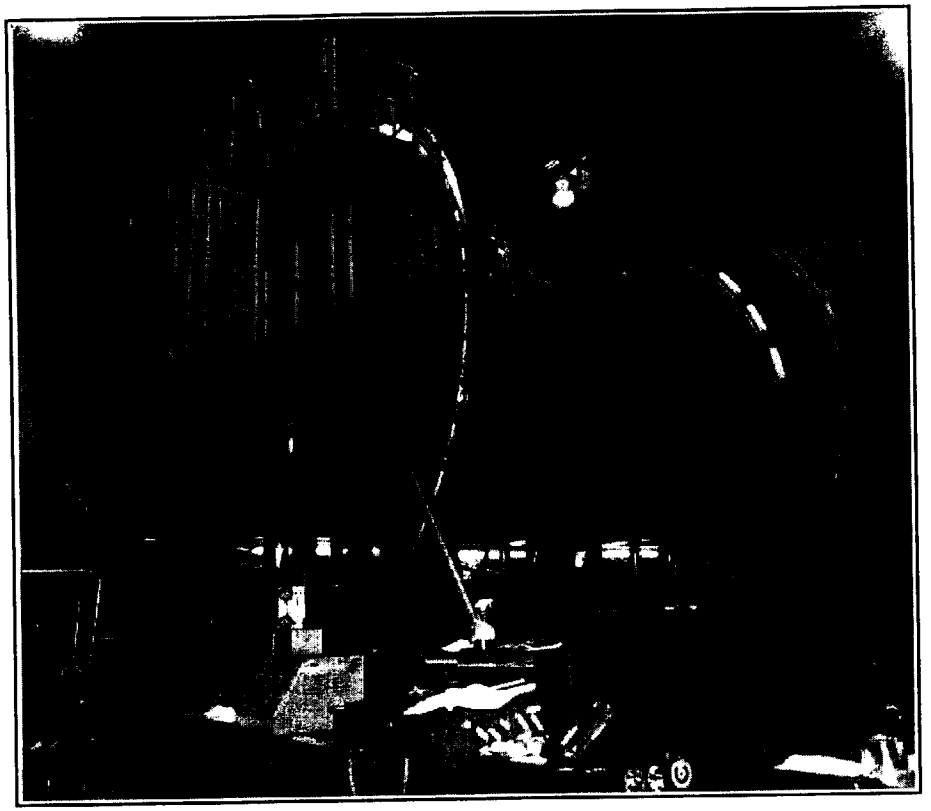
Friction Stir Welding on the External Tank

Today's Fusion Tooling



Existing Short Barrel Weld Tool

Vertical VPPA welding of LH2 Barrel 1 and LO2 Barrel

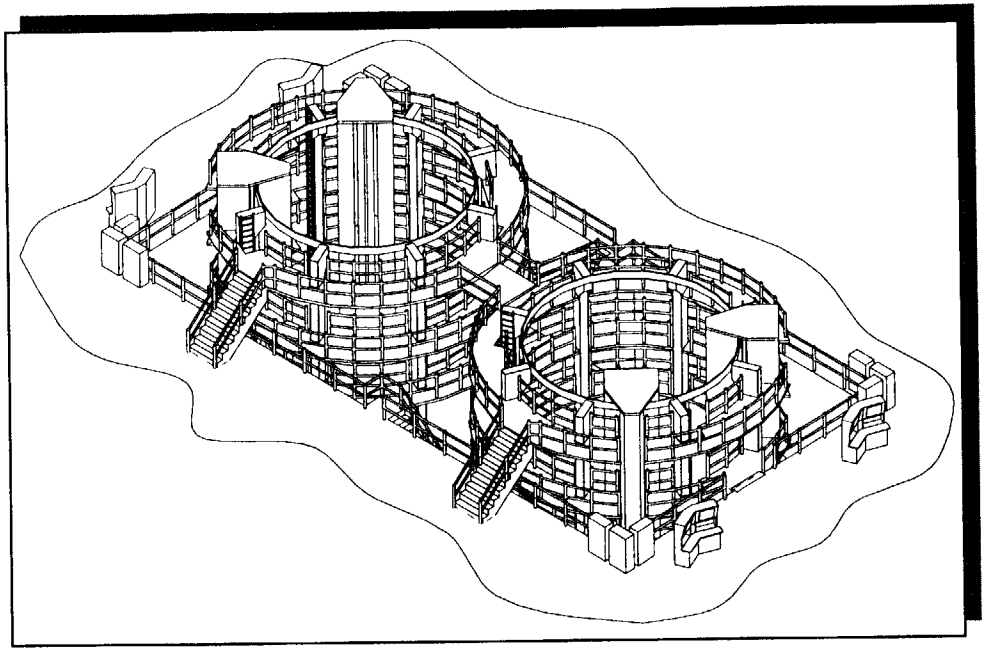


Existing Long Barrel Weld Tool

Horizontal SPA welding of LH2 Barrels 2, 3 & 4

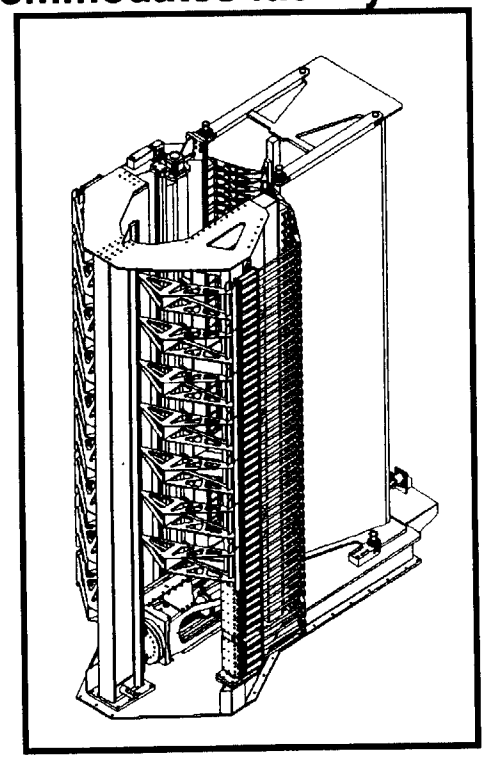
Friction Stir Welding on the External Tank

Tomorrow's FSW Tooling



Mechanical

- Universal Tool that handles all barrel configurations
- Utilizes Retractable Pin Tool for tapered welds
- Provides access to entire barrel
- Integral test fixture
- Reacts clamp and force loads
- Accommodates facility hook height



Electrical Controls

- Complete Automatic Operations
- Process observation cameras
- Automatic Seam Tracking
- Touch Screen Operation
- Process Data Acquisition and Archival

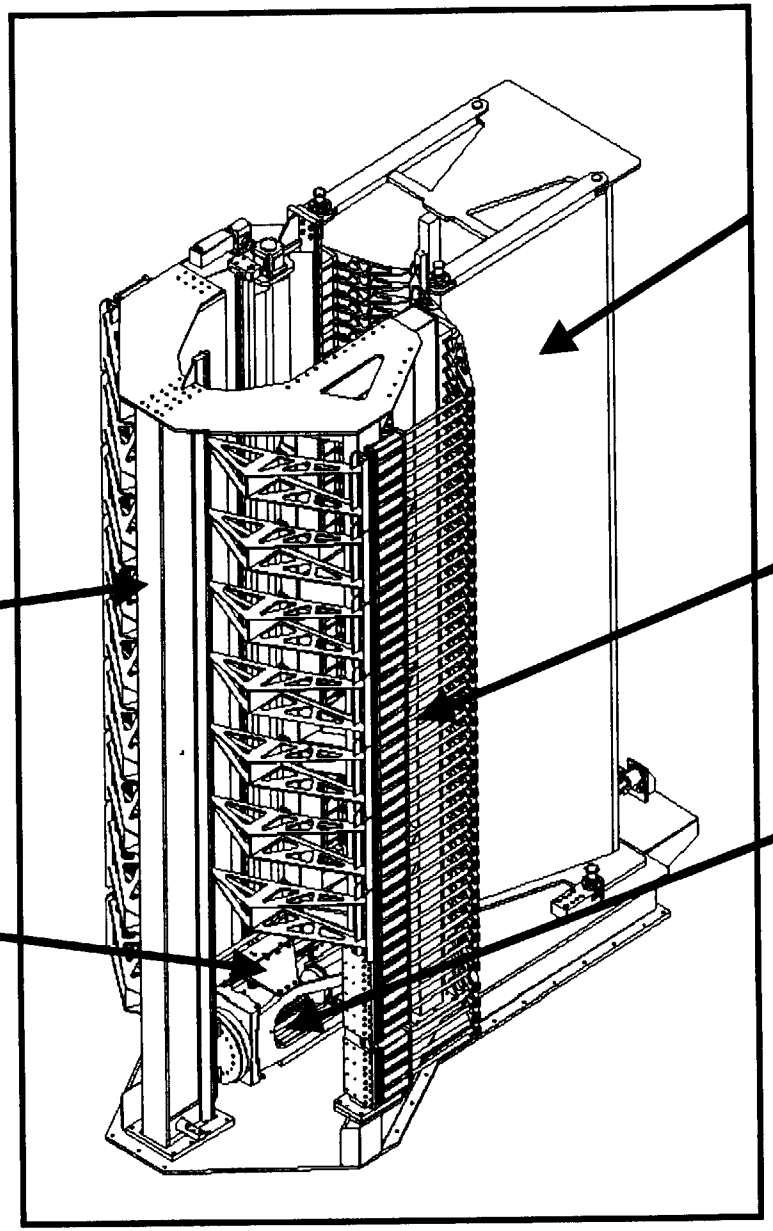
Friction Stir Welding on the External Tank

FSW Tooling

- Contract Awarded to General Tool Company (GTC)
  - Two Production Tools
  - One Process Development / Trainer Tool
- Prototypes Demonstrated
  - Clamping
  - RPT Measurement
  - Force Control
- Design Complete
  - Production Tool
  - Development/Trainer
  - Platforms
- Fabrication in work

Friction Stir Welding on the External Tank

Production Tooling



Seam Tracking
Joint Gap
Thickness Offset

Movable Anvil Section

Individually Actuated
Pneumatic Clamping

Force Balance
System

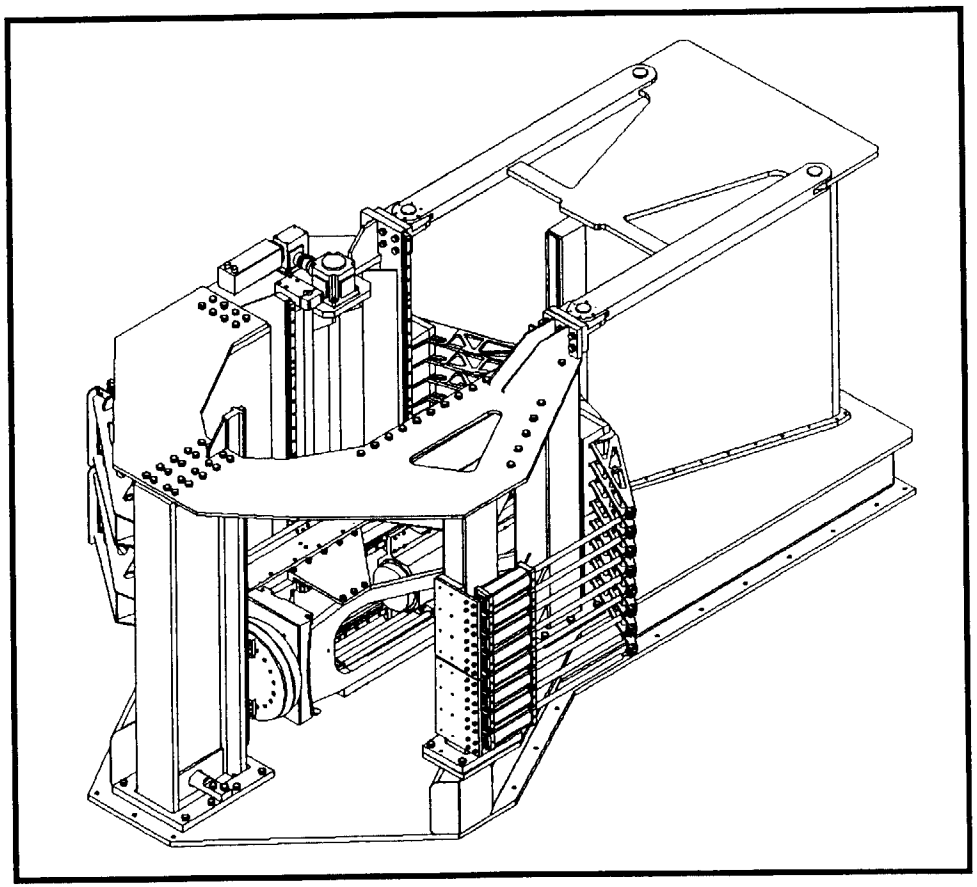
Position and Load
Control Capability

Adjustable
Pin Tool

Friction Stir Welding on the External Tank

Trainer

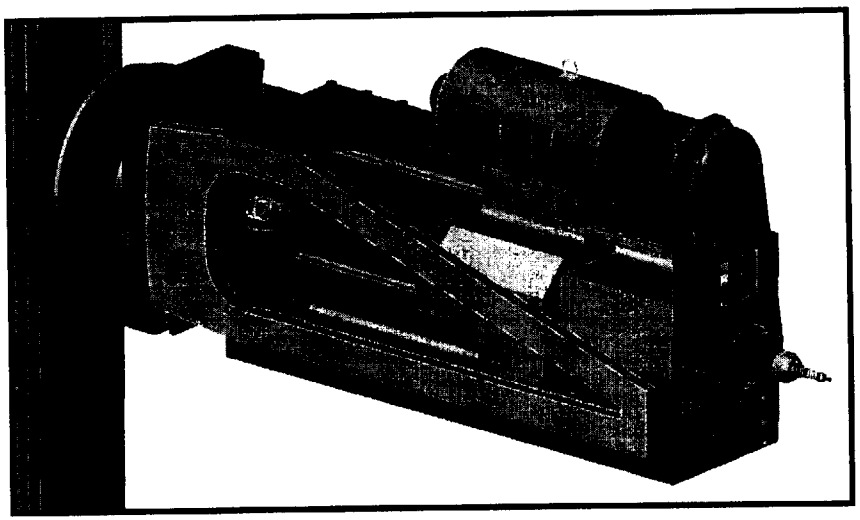
- "Knock-off" of Production Tools
  - Force Balance
  - RPT
  - Fixed anvil column
- Spindle Torque measurement capability
- 48-inch panel length

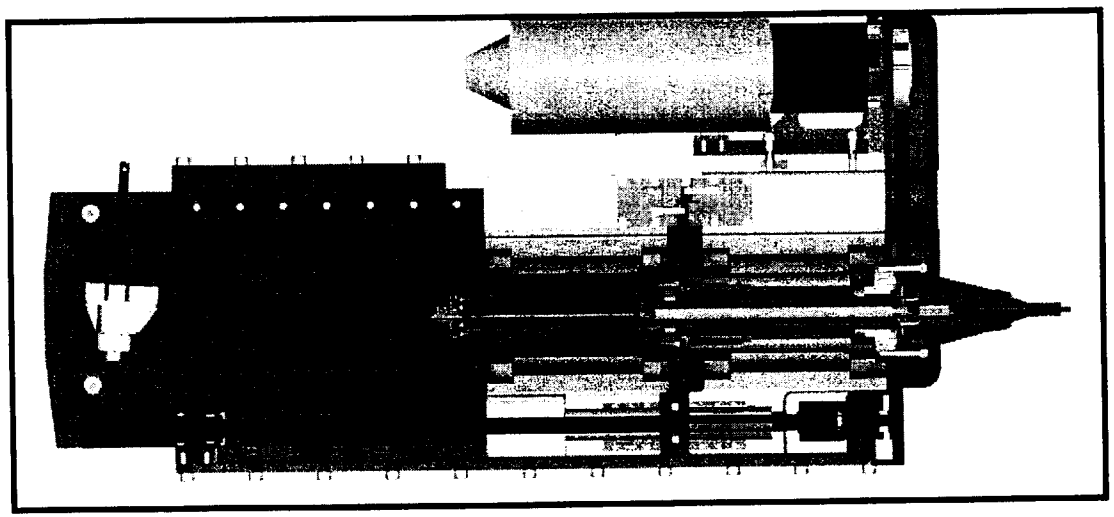


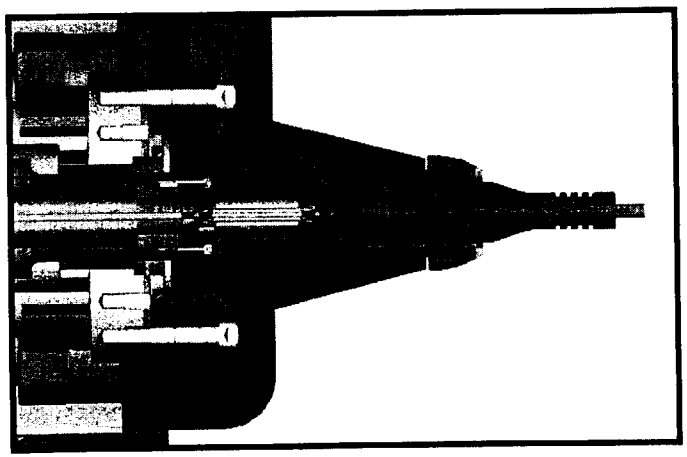
Friction Stir Welding on the External Tank

Weld Head

- Force Balance Plunge Load
- Retractable Pin Tool
- Pin Growth Measurement & Compensation



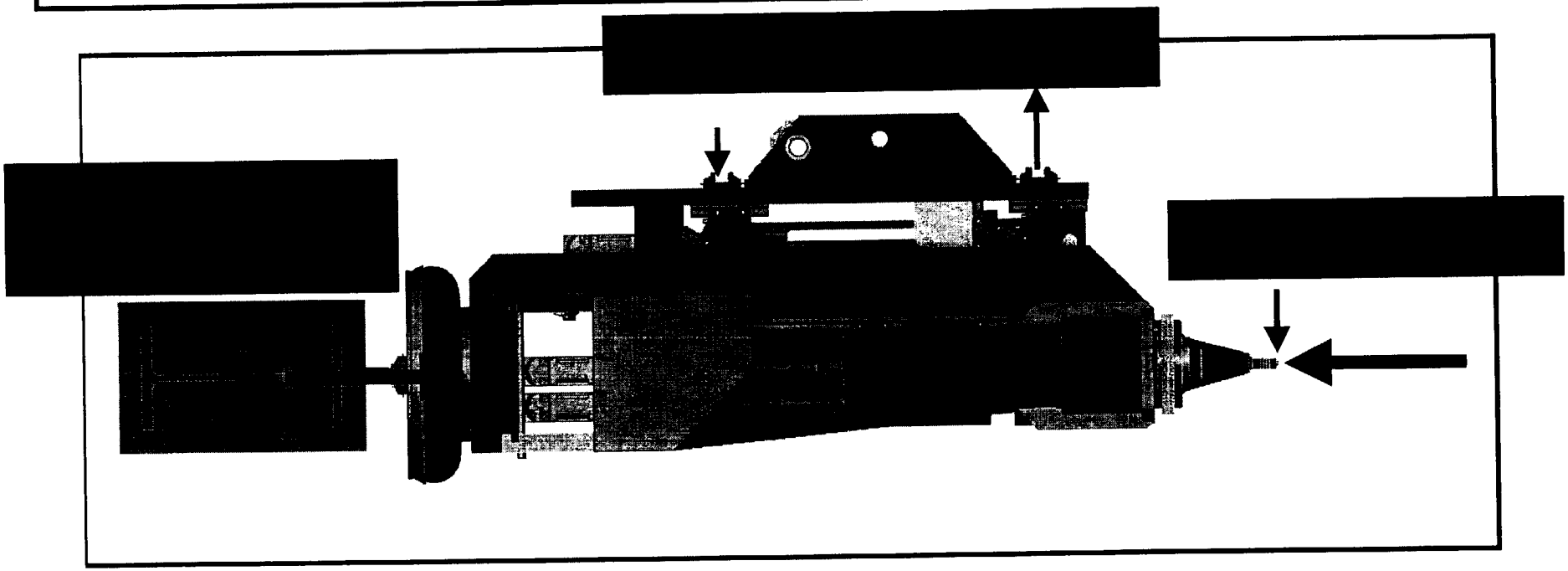




Friction Stir Welding on the External Tank

Force Balance - Spindle

Active Force Balance System - Firestone AirStroke Cylinder, Pressure regulated and monitored by control system.

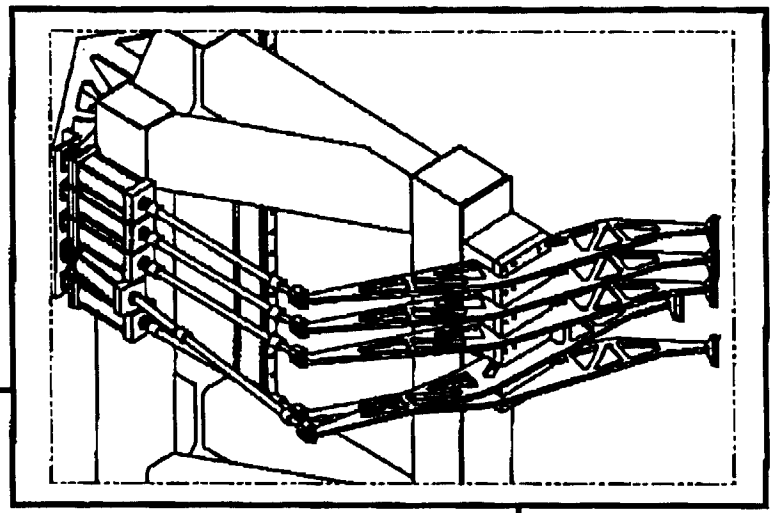


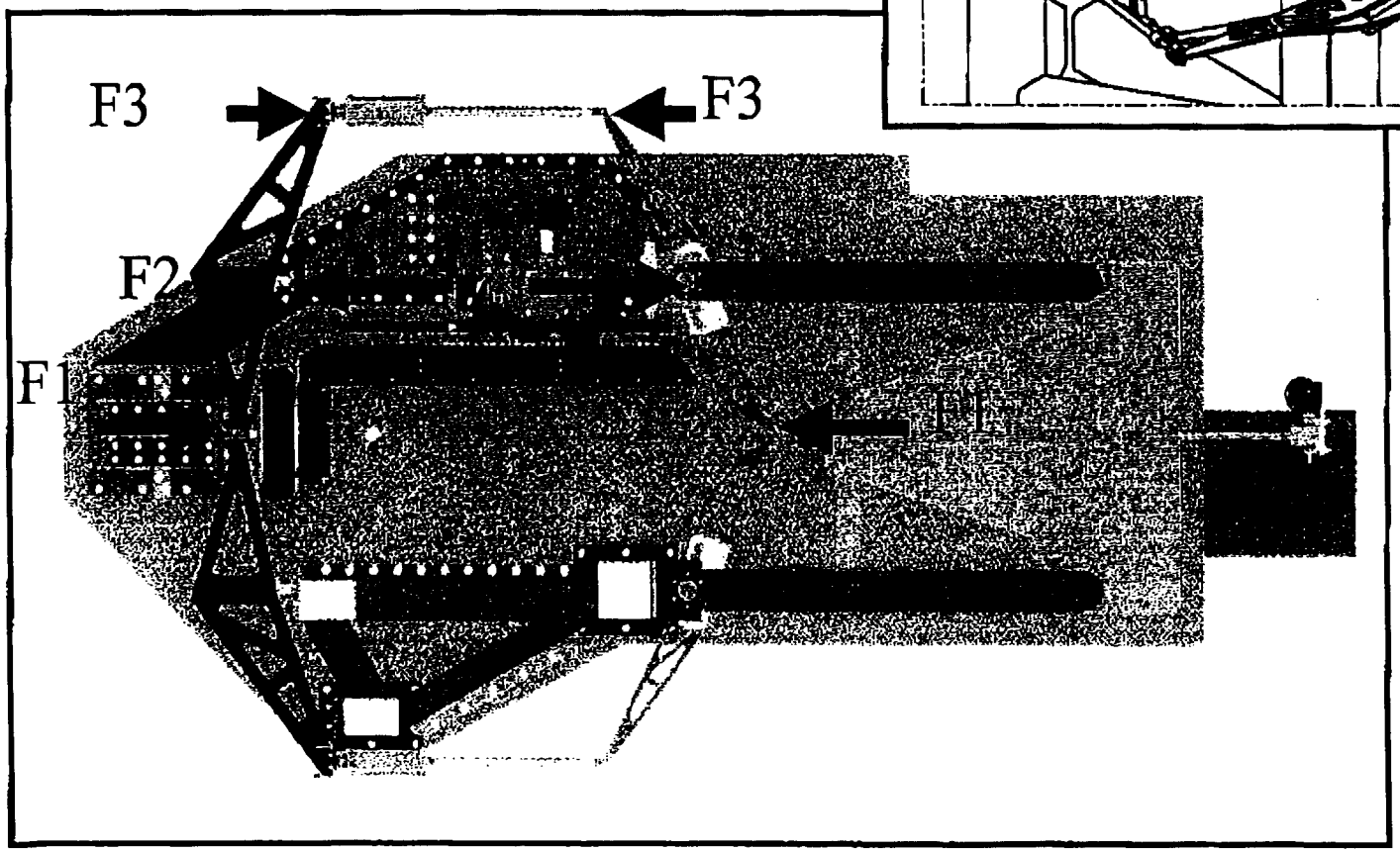
Force balance system transfers loads and associated deflections to a secondary structure, minimizing process-critical deflections while meeting stringent requirements for maximum floor load.

Friction Stir Welding on the External Tank

Force Balance - Clamping System

- Passive Force Balance System
  - 90 Individual Clamp Arms
  - Fault Tolerant Pneumatic Actuation

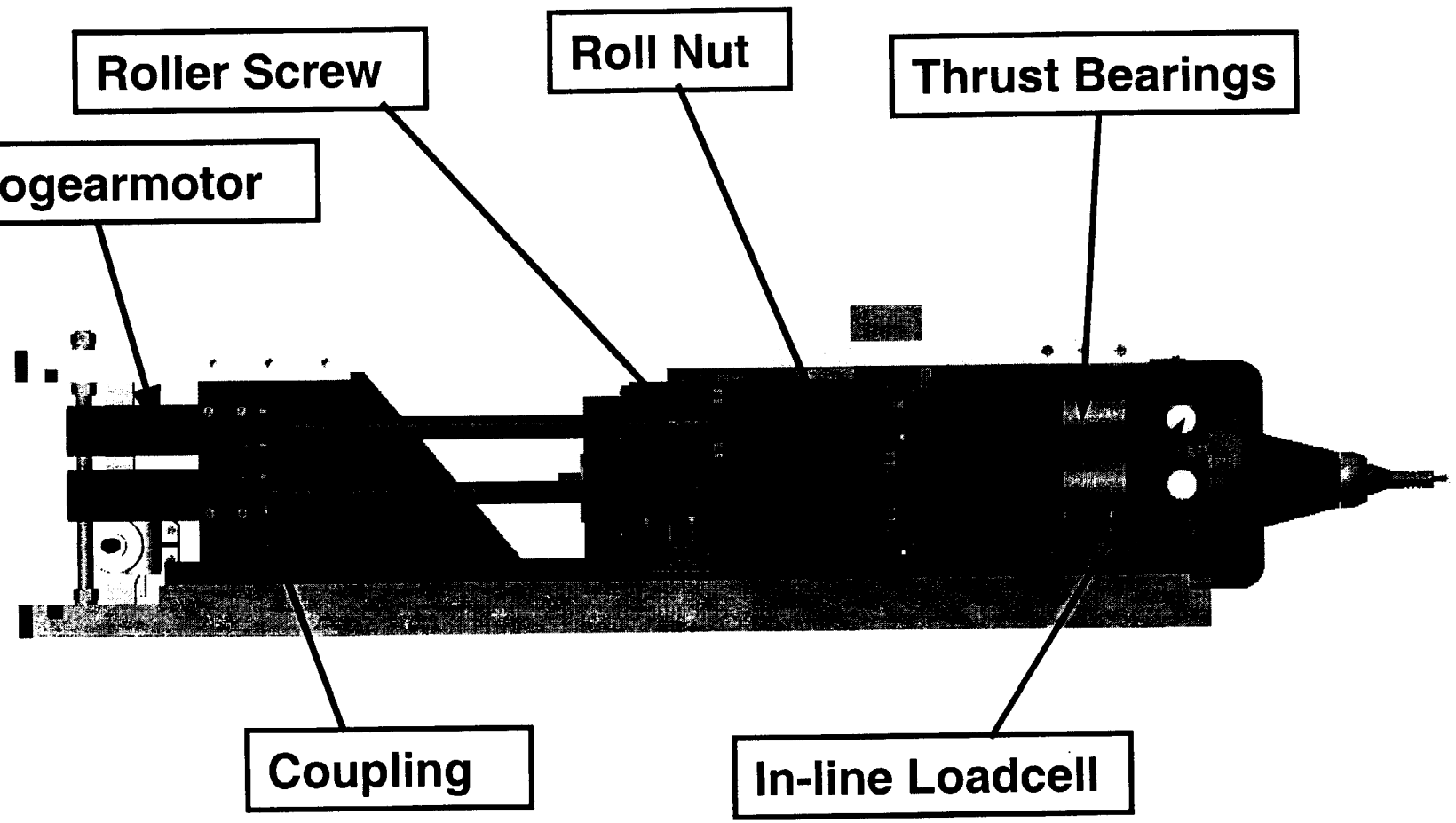




Friction Stir Welding on the External Tank

Plunge and RPT Axes

Independent Axes - Each capable of independent load or position control.

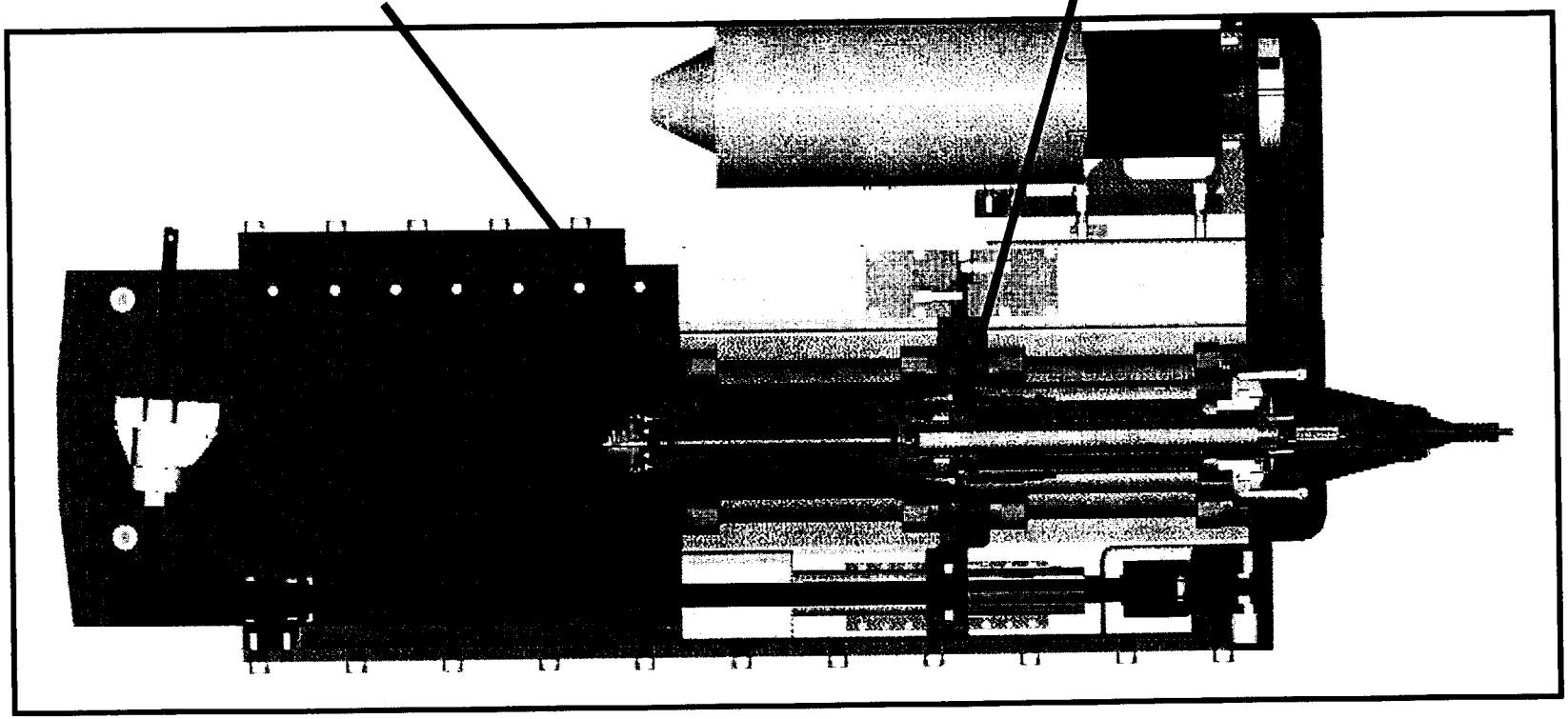


Friction Stir Welding on the External Tank

Retractable Pin Tool

Rotationally coupled to main plunge axis, independent linear motion.

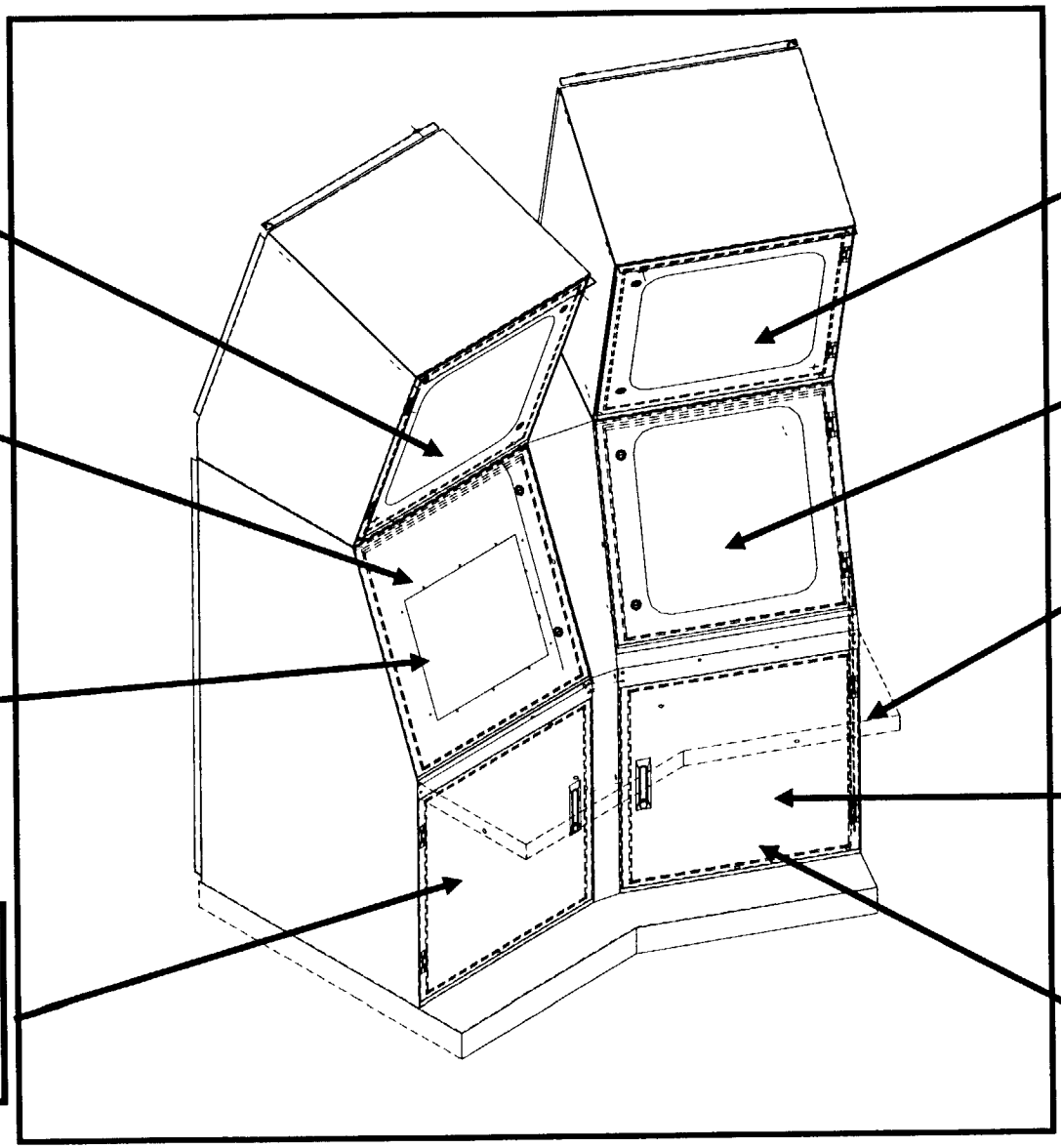
Separate Spindle Block



Separate pin and shoulder components provide adjustable pin length required for conducting taper thickness welds.

Friction Stir Welding on the External Tank

Control System



Process Video Monitor

Convenience Ports & E-Stop

MMI PC Touchscreen

Video Recorder A-B Switch Screen Splitter

Seam Tracking Monitor

Datalog Station Monitor

Datalog Station Keyboard

Datalog Station CPU

Ethernet Hub MAF LAN Port

Friction Stir Welding on the External Tank

Control System

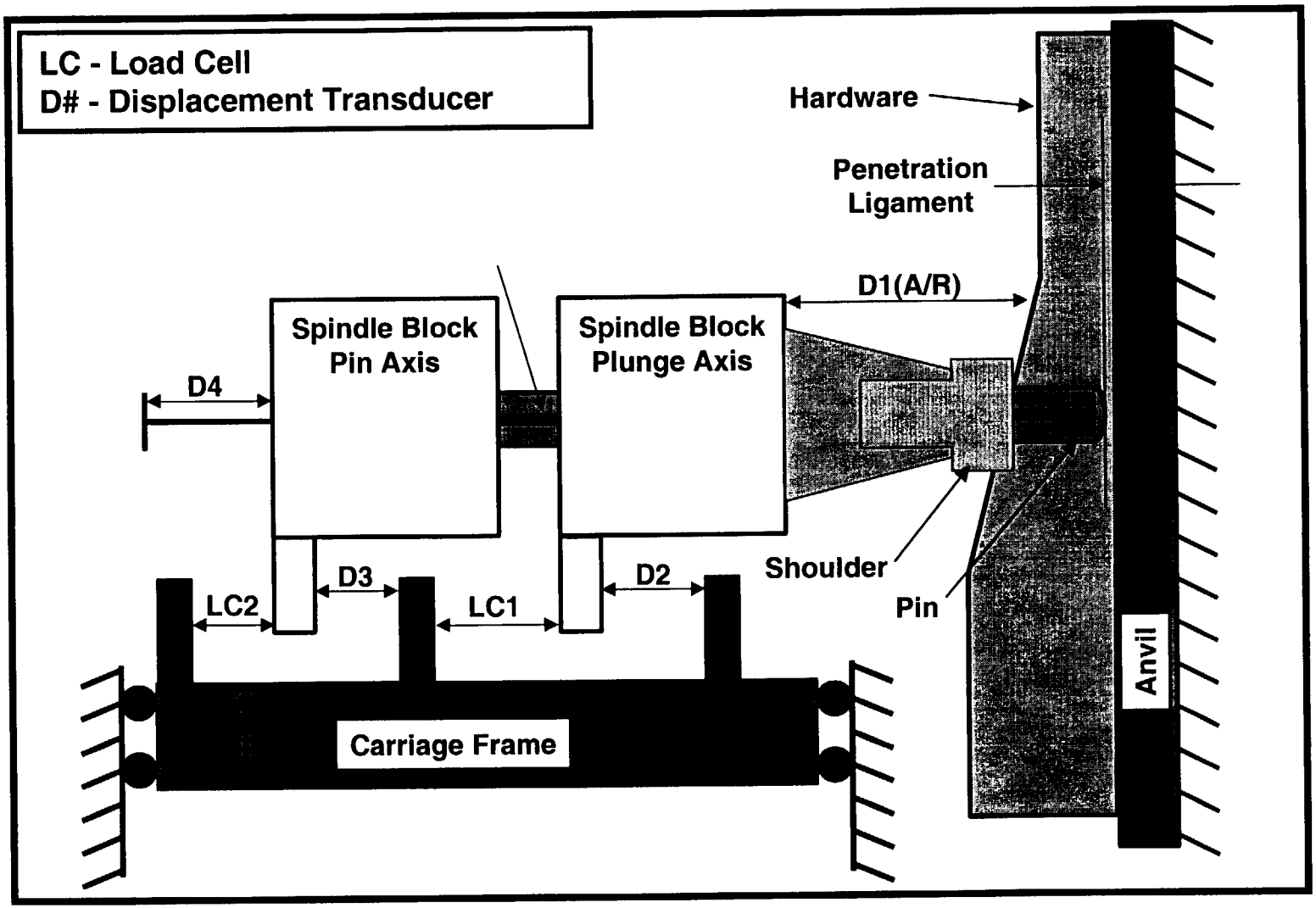
- PLC based tool control; Galil based motion control for the welder
- FSWelder
  - Independent Position or Load control of plunge and pin axes
    - Position Control Mode - Controller maintains a position set point with load limits induced to ensure process stability.
    - Load Control Mode - Controller maintains a load set point with position limits induced to ensure process stability.
    - Mode switching capability during the weld process.
  - Independent measurement of plunge and pin axes position relative to carriage via magnetostrictive transducers.
  - Pre-weld measurement of part surface relative to plunge axis to obtain thickness offset measurements on both sides of weld centerline (Laser sensors).
  - Pre-weld measurement of weld seam centerline (Optical System).
  - Pre-weld measurement of weld joint gap (Optical System).

Friction Stir Welding on the External Tank

Control System Schematic

- D1(A/R) - Laser sensors
- D2, D3 - Magnetostrictive Transducers

- D4 - LVDT
- LC1,2 - Load Cells



Friction Stir Welding on the External Tank

Control System

- Operational Approach
  - Constant thickness welds
    - Determine part surface location and centerline location during pre-weld scan using laser sensors and optical system
    - Control the position of a fixed length pin tool using plunge axis mechanism
    - Part surface location and weld centerline path from pre-weld scan data used to control the process
    - Active measurement of part surface location used as a "sanity check" during the process
  - Taper thickness welds
    - Generate anvil contour map prior to installing hardware
    - Determine part surface location and centerline location during pre-weld scan using laser sensors and optical system
    - Control the shoulder load
    - Position pin tip based on the anvil map, compliance data and the pin measurement system data

Friction Stir Welding on the External Tank

Implementation Status

- Tool Design is Complete and Fabrication Underway
- Force balance, clamping system and pin measurement system prototyped and demonstrated
- Facilities Modifications Nearing Completion
- Project Is on Target to Weld Flight Hardware in July of 2002
- Flight Hardware Projected to Fly in 2005