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Panel Loaders for A380

Chuck Hopper, Theodore Karagias, Laurence Durack
Electroimpact, Inc.

Al Ferguson, Jim Rowe
Airbus Industries, UK

ABSTRACT

The Airbus A380 is among the largest aircraft ever built. The wing panels for the Airbus A380 are massive some being as long as 33M and weighing in excess of 4000kg. Large wing skin panels are inherently difficult to handle and the immense size of the A380 makes handling that much more difficult. The crane and wing assembly crews tasked with building these wings in Broughton UK must install and remove these panels multiple times throughout the build process. The task must be preformed accurately, safely, without damage to the wing structure, and within ever-present flow time pressures. The Airbus engineering team of Alan Ferguson, Allan Ellson, and Jim Rowe challenged Electroimpact to deliver a machine and material handling process to automate the installation and removal of wing panels within in the A380 wing assembly jig. The machine must safely handle these large wing skin panels and ease the panel and stringer assemblies into the tightly constrained socket created by the ribs, spars and stringer clips that make up the wing substructure.

INTRODUCTION

Historically there are two basic panel-handling techniques employed to position wing to aircraft sub structure. The first is to constrain panel form with large strong backs. The second technique is to bring the panel into form as it is pulled up to the sub structure. Airbus challenged Electroimpact to develop an all-new approach. A method for loading and unloading wing panels that:

- Accurately positions the wing panels to the sub structure
- Provides control over wing form
- Provides fine positioning control over the length of the panel
- Provide simple operator controls and feedback systems to facilitate a large operator pool.
- Limits the loads imparted into the panel to avoid damage
- Controls the position of the skin assembly as the stringers are engaged into the ribs (the last 75mm)
- Stows away when not in use
- Serves all three wing jig levels

PANEL LOADERS

Electroimpact developed a multiple arm panel positioning system designed around the unique constraints imposed in wing manufacturing. 22 arms are used to position panels on 4 jig faces and 3 separate floors. Up to 6 telescoping arms per wing panel extend out 3M from the jig columns. The arms attach to the wing panels at discrete lift points distributed along the length of the panel. The distributed lift points provide the attachments necessary to manage panel position and form over the length of the panel.

The distributed support points necessary to manage the panel form also present the most significant challenge faced by the Panel Loader design team. With up to 6 support points this configuration is statically indeterminate. As the panel is positioned and constrained into contour the wing substructure twists, bends, and kicks as it reacts the forces applied at the lift points. The lifting equipment then reacts to the panel and again the panel to the equipment. The reactions are both unpredictable and potentially excessive placing both wing structure and assembly personnel at risk.

The Electroimpact design team of Ted Karagias, Chuck Hopper, Laurence Durack and Remco Spiker changed the rules. The key was to reduce the problem from an indeterminate set of loads and reactions to a simple determinant 2 point lift. Two Panel Loader arms are set to position control. All other arms seek an assigned load. Regardless of how the panel behaves the load seeking arms adapt the vertical height to achieve the designated load. This basic simplification is integral to the success of the panel loaders.

The vertical axis is servo hydraulic. A dedicated axis controller continually monitors both the load on the wing panel and the position of the arm. For a stationary panel all arms servo on a fixed position. With any coordinated move the load seeking arms servo on load while the two position arms continue to servo on position. With completion of the move all arms return to position control. The transition between load and position control is seamless providing smooth control through vertical, extend, and rotate operations.

The operator pendant is wireless and designed to support both automated and semi automated load processes. Load feedback is provided at each arm to clearly indicate how force is distributed across the panel. Throughout the process the operator is free to position themselves as necessary to guide the panels on and off with unprecedented control.

PANEL LOADER SYSTEMS

At a high level the concept for the Panel Loaders is straight-forward. A set of arms extend from columns and attach to a wing panel. During gross movement two arms servo on position and all remaining arms seek load. Fine movement has all arms seek position with loads continuously monitored. The implementation however is more challenging and represents a very complex integration of control logic, closed loop hydraulic servo control, along with the electrical and mechanical packaging. These elements all designed to integrate with the A380 wing major assembly jig structure and systems. All packaged to ensure safe operation with a simple operator interface and meaningful operator feed back. This section outlines in detail the various systems that make up the Panel Loaders.

Figure 1, Panel supported by Panel Loaders in wing form prior to engagement with sub-structure.

- 22 arms cater to all four wing faces, Starboard/Port Top/bottom. The four faces are controlled independently except to share a single PLC, wireless pendant, and common hydraulic supply.

Figure 2, Eleven Panel Loader arms deployed on 2nd level empty starboard jig.

- Each arm requires control of up/down positioning (Y axis), load (F), in/out (Z axis), arm deploy angle (A axis) and end effector angle (E axis). Due to the critical nature of the Y and F axis control Rexroth HNC 100 is dedicated to each arm. With a 4ms scan time and seamless transition between position and load control the HNC is ideally suited. An added benefit is the ability to make real time measurements. This proved invaluable when it came to tuning the axis. Cost concerns due to the need for 22 HNC's was offset by Profibus enabled I/O on the HNC. With 4 analog input, 4 analog output, 8 digital inputs and 8 digital outputs available the need for additional I/O for the arm was reduced to 16 digital inputs and 16 digital outputs.
- Using the HNC reduced the performance requirements of the overall controller. With the HNC taking over control of the critical axis the PLC speed was no longer an issue and one PLC is used to control everything. The single PLC approach also simplifies the interactions with the single HBC-radiomatic wireless pendant and hydraulic pump as it removed the requirement of passing information between separate controllers. The controller is a Siemens CPU315-2DP with integrated Profibus. The HNC's and any other I/O connect to the PLC via this single Profibus. The total length of the Profibus network is 400M and it runs at 500kHz.

Figure 3, HNC controller

- The arm I/O required for this setup amounted to 320 I/O points per arm or 7040 I/O points for the 22 arms, a lot of I/O. Additional to this I/O is the wireless pendant with 72 points of I/O and the communication with the hydraulic pump with 16 points of I/O, resulting in a total count of 7120 I/O points. Each arm requires two Profibus nodes one for the HNC and one for the additional I/O block. The wireless pendant uses one node and the I/O for the hydraulic pump another giving a total of 46 nodes
- The system also includes 4 Siemens MP270B touch screens operator consoles. Each wing face has a dedicated consol mounted central to that face. The touch screens communicate over the same Profibus network as the I/O. A fifth remote display is portable with a 30M-hookup cable providing a portable consol that can be set up anywhere on the jig.

Figure 4, Hydraulic enclosure (top) Electrical enclosure (bottom) typ each arm. 4 locations include operator touch screen.

- The PLC program allows configuration data to be stored for eight different panels per face. Furthermore, three different sets of configuration data are available to setup on each panel. The first piece of configuration data required is the floor to deploy on (ground, first or second floor), and the number of arms required. Next is the entry of the axes various positions/loads for each automatic move. Examples of positions are the axes position for picking up the panel from the crane and the position for removing the panel from the wing. These positions may be typed in or taught by jogging to position and teaching. A total of 17 words are used for storing this data per arm. With 8 panels and 3 sets available that's 403 words (8*3*17) per arm. Adding 60 words for calibration data etc increases it to 463 words per or 10186 words (463*22) for the entire system. This is well within the capabilities of the Siemens CPU315-2DP PLC.
- The system has an extensive error reporting system. These errors have levels that are settable and can be setup to either kill the system, flag the error or to do nothing. Most errors are normally set to kill the system. Independent of the error, errors have different scope. For example if the hydraulic pump dies all faces will die and give an indication of the error. However if a HNC dies only the affected face will report the error. Thus maintenance may be carried out on one face without fear of affecting another face. Power down a Profibus node and only the face it is used on is affected. The other faces don't care.
- A detailed messaging system is also employed for the E-Stop system. Each face has its own loop and consists of various bumper switches. These local loops are also tied into a jig E-Stop loop that kills everything.

Figure 5, Arm deployed from Jig column, bumper strips top and bottom guard against crushing hazard.

- Operator feed back is provided at multiple locations and levels. Each touch screen displays detail operational information including position, arm angles, operational mode, the load on each arm and provides access to detail error handling. Lights on the pendant indicate which arms are active and blink when arms are moving. White LEDs on the arm echo the same information. A color LED light array located on each arm indicates load and ensures that the operator is fully cognizant of the loads applied to each panel. The load indicator is driven directly from one of the HNC analog outputs.
- Panel loaders stow in the jig columns and deploy on 3 separate floors. The operator must establish which panel is being manipulated. Depressing the deploy button calls the specific arms to the correct floor and deploys them from the columns.
- The vertical axis is operated by a hydraulic cylinder and hoist cable run inside the jig column. The cylinder is configured with counter balance valves on both blind and rod ends. Buried within the vertical cylinder is a MTS Temposonics SSI linear

transducer. The transducer is connected directly to the HNC. Load is measured by a Honeywell Sensotec load cell. The load cell and amplifier are located at the end of the arm and directly measures load on the effector. The load cell is connected to one of the 4 HNC analog inputs. Thus both the load and y position are accessible to the HNC in real time. The HNC echoes both Y poison and load to the PLC.

Figure 6, Linear scale buried inside cylinder measures vertical position.

- Each arm utilizes a Bosh Servo solenoid valves controlling the main cylinder. The valve is driven directly by the HNC taking advantage of the 4ms scan rate.
- A total of 5 additional hydraulic circuits are driven by a combination of solenoid valves, directional flow restrictors, pressure regulators and counterbalance valves. 22 12 position manifolds provide hydraulic service one at each arm.

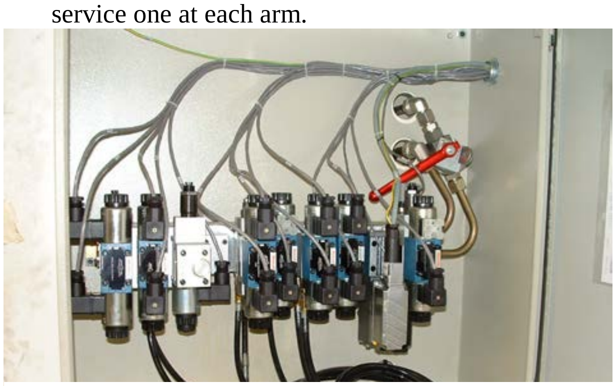


Figure 6, Hydraulic manifold typical each arm.

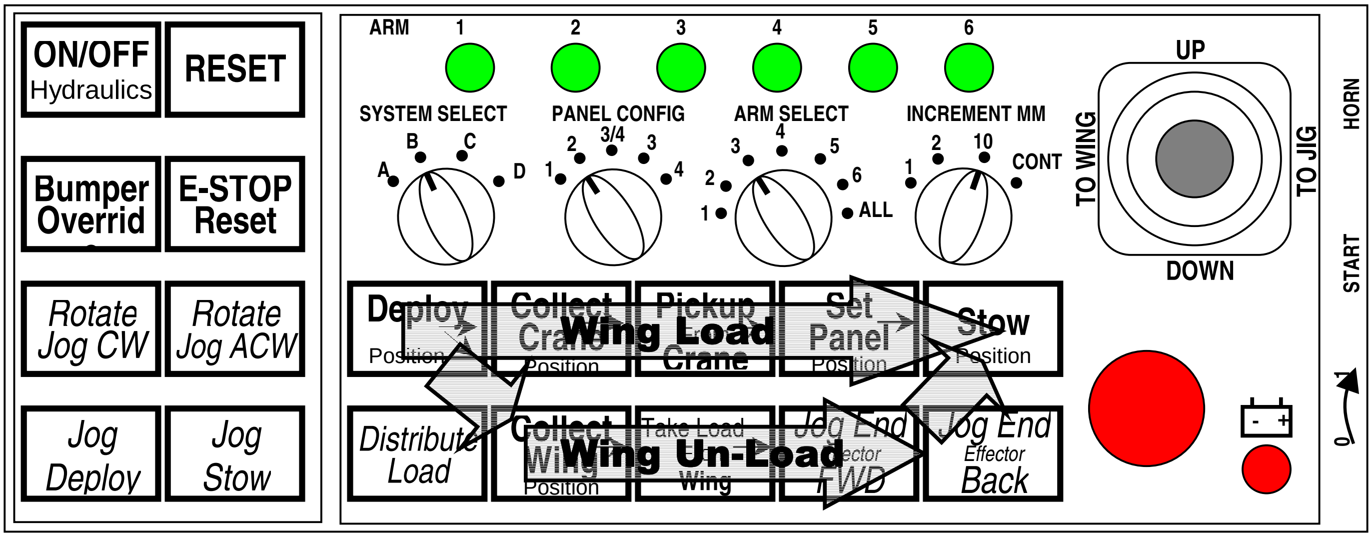
Figure 7, Electrical controls typical each arm.

Figure 8, Panel shown during removal process. Panel is completely supported by panel loader arms and then drawn away from sub structure.

OPERATOR ORIENTED PROCESS

Along with the panel loaders is a wing load/unload process. The wireless pendant is configured to follow a process flow starting with a call to floor and deploy, through the pick panel from the crane, set panel to wing, engage panel, and finally release and stow panels loaders.

Sections of the pendant support Load and Unload processes. All are all hold to run.



Wing Load Process Buttons

Deploy Position	Moves Loader to appropriate floor, deploys arm(s) and raises arms to height for End Effector adjustment.
Collect Crane Position	Moves arm(s) to programmed location and pitches end effector forward ready to receive panel.
Pickup From Crane	With all balls engaged on panel will apply a small up force to the balls and pitch end effectors back to a programmed angle.
Set Panel Position	Activates load seeking and moves panel to a location slightly disengaged from ribs
Stow Position	Moves the arm(s) down and stows them. End Effector must be in stow configuration.

Wing Unload Process Buttons

Deploy Position	Moves Loader to appropriate floor, deploys arm(s) and raises arms to height for End Effector adjustment.
Collect Wing Position	Moves arm(s) to programmed position and pitches arms fwd to accept remove panel from wing.
Take Load From Wing	Distributes programmed load on all arms in preparation for removing dowels and slave bolts.
Jog End Effector FWD	Pitches End Effector Fwd
Stow Position	Moves the arm(s) down and stows them. End Effector must be in stow configuration

CONCLUSION

The panel loaders successfully loaded its first wing panels in March 2004. Since then they have demonstrated the ability to load and unload wing panels in a smooth well controlled moves. They have also provided the Airbus production teams unprecedented control over their process, timing and final panel fit.

The programmed load distributions and programmed positions come very close to an ideal "one button" automated load. Equally as beneficial is the ability to apply a programmed load distribution and gently extract the panel from the wing ribs. The panel loaders have changed the panel setting from a crane crew "Heavy Gang" concentric process to an assembly team concentric process. The assembly teams have the flexibility to support and adjust the panel through the tack fastening process placing the handling tools in the hands of the individuals who benefit most from the panel loaders.

Figure 9, following a successful panel load.

ATTACHMENTS

Attachment 1, 1980-5010-00 Sheet 3
Panel Loader General Arrangement.

CONTACT

Charles Hopper
Electroimpact Inc.
Email: charlesh@electroimpact.com

Laurence Durack
Electroimpact, Inc. .
Email: laurenced@electroimpact.com

Ted Karagias
Electroimpact, Inc. .
Email: tedk@electroimpact.com

Al Ferguson
Airbus Industries, UK

Al Ferguson
Jim Rowe, UK

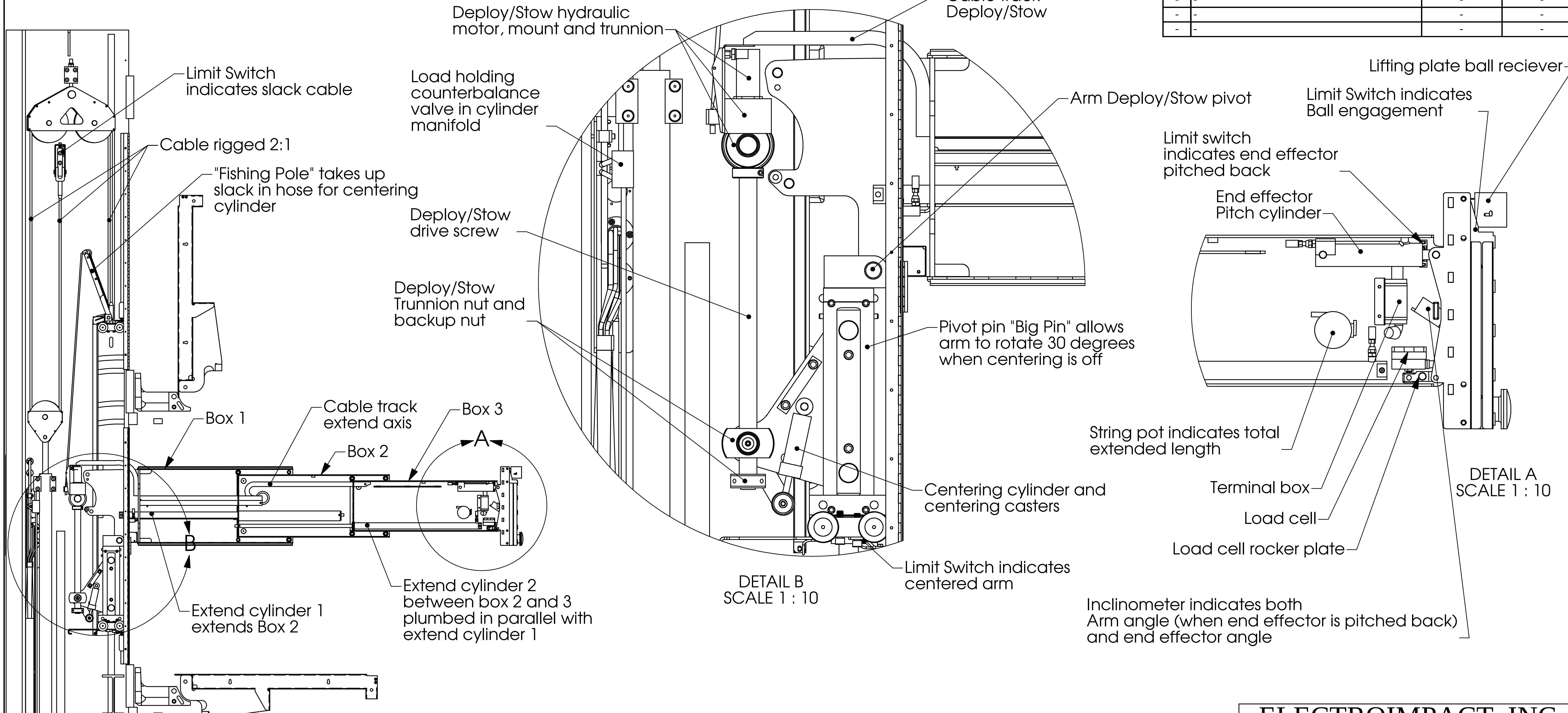
DEFINITIONS, ACRONYMS, ABBREVIATIONS

Abbreviations & Definitions

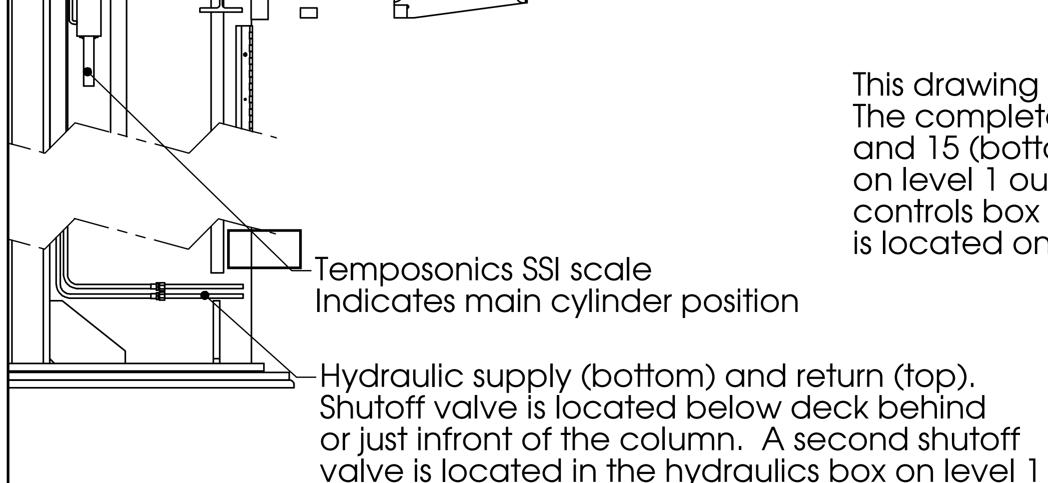
HNC:	Bosh Rexroth Digital Servo Drive controller for Electromechanical and electrohydraulic drives
PLC:	Programmable Logic Controller
Profibus:	Process Field bus
I/O:	Input/Output
LED:	Light emitting Diode
NC:	Numerical Control
E-Stop:	Emergency stop
SSI:	Synchronous Serial Interface

Attachment 1, Panel Loader General Arrangement

Rev	Description	Revised By	Date
New	New Release	C Hopper	-
-	-	-	-
-	-	-	-
-	-	-	-



This drawing shows a cutaway view of a panel loader arm installed in the column. The complete panel loader installation consists of 22 arms installed in columns 5, 7, 9, 11, 13, and 15 (bottom face only). Each arm has a dedicated electrical and hydraulic box located on level 1 outbrd column face. On column 9 starboard bottom face there is a single PLC controls box and wireless pendant transceiver that services all arms. An operators console is located on column 9 of each face.



ELECTROIMPACT, INC.
4606 107th Street SW, Mukilteo, WA 98275

Unless Otherwise Specified:
Dimensions are in inches
Surface finish shall be 125 microinch or better
Remove all burrs and break all sharp edges
All projections are third angle

Drawing Title:
Panel Loader General Arrangement

Drawing Number: 1980-5010-00
Sheet: 3

Engineer: Chuck Hopper
Phone Number: (425) 609-4280
e-mail: charlesh@electroimpact.com