Robotic Welding Cell Design Final Report

Sponsoring Company: Cormer Aerospace

Advisor: Mal Symonds

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Dear Dr. Labossiere,

The C.A.D.D Consulting group is pleased to present the following report detailing the new robotic welding cell that has been selected.

As previously requested, C.A.D.D Consulting has sourced an automated welding cell that is capable of performing 3D welds on small to medium sized parts. The final designed welding cell is a turn key automated welding cell and will require minimal human interaction during the welding process, aside from loading and unloading parts. The welding cell is capable of welding a variety of metals and will perform simple and complex welding operations. The welding cell has been designed for constant operation during working hours while keeping cost in mind.

A final list of installation requirements, cell capabilities and a suggested bill of materials has also been included in the attached report. In addition, high level financial details such as an estimated investment cost and estimated operational costs have also been provided.

The C.A.D.D Consulting group would like to thank you for your cooperation and support over the course of this project. If you have any further questions in regards to the project, you can contact our project manager Denis Silva at 204-451-3137. Thank you for your time.

Sincerely,

C.A.D.D Consulting

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Executive Summary

Cormer Group Industries has requested C.A.D.D. consulting to develop or source a suitable welding cell in order to obtain future contracts. Since automated welding is a new process for CGI, it has been stated that the subject welding cell should be able to handle small to medium sized parts, made from a variety of different materials. The welding cell should also be able to handle both simple and complex welding requirements. Finally, the welding cell is required to be a turnkey system which means that the designed or sourced cell should be complete and ready for operation without further part or component sourcing.

After discussion within the C.A.D.D. consulting group, it was determined that designing a new type of welder and process for the subject problem would not only be unnecessary, but it would not benefit the customer due to the high cost associated with designing a new robotic welding cell. Therefore, multiple welding cell suppliers were contacted for information and the most suitable welding cell was selected for the required task. Lincoln Electric's System 50 HP Platform was selected as being the most suitable system for CGI's requirements due to the cell capabilities and cost. The system contains an automatic robotic welding system, complete with a computer controlled fully integrated robotic welding arm and a hand held operating system. The system will have two different bays in order to allow the system to work consistently as one part can be welded in one bay while another part is loaded in the second bay. The sourced system is also water cooled in order to allow complex welds to be completed for long periods of time (i.e. entire work days). [1][2]

In conclusion, the sourced Lincoln Electric 50HPwelding system will not only meet all of the CGI's current needs, it will exceed many of the customer's needs in order to allow the system to be used for more than the current requirements and allow CGI to bit on multiple new contracts in the foreseeable future. This will all be provided as an installed unit for the cost of $273 000. [1] (See App. A for complete quote.)

Introduction

A new contract is to be awarded to Cormer Group Industries (CGI) on the terms that the work is done by robotic welding. Currently, CGI does not have any in-house robotic welding capabilities, and all required welding is done by either an internally employed welding specialist or an outside company. Robotic welding is an entirely new process for CGI, and therefore, robotic welders must be researched and reviewed to ensure all the customer's requirements are met. The implementation of the robotic welder is to allow CGI to successfully obtain the current contract work and to aid in obtaining new work contracts in the future. A robotic welder will also save time and money for CGI by performing welding requirements in house. CGI is looking for a turnkey robotic welding system, with a bill of materials that allows for complete installation and implementation. [2]

Customer Needs

CGI has recently been sub-contracting out welding projects due to their lack of robotic welders. CGI currently has a welding bay, which is operated solely by a welding technician. This does not meet their future requirements. Due to confidentiality issues, CGI's request is to have an in-house robotic welding process to obtain specialized projects. CGI would like to have a robotic welding cell that can perform 3-Dimensional non-linear welds. The welder should also be capable of performing thick and deep welds. The welder needs to be capable of welding small to medium sized part, with a size up to 400mm in length, and can be made from a wide variety of metals. The welder also needs to maintain a high level of precision with minimal human interaction. Overall, the welder should be cost efficient during operation and for the initial setup. [2]

In order to perform 3-Dimensional welds with high precision, a specialized holding mechanism will be required. This holding mechanism may require loading from an outside source, such as a welding

technician. To ensure smooth operation, the welding cell size should be appropriate for a variety of tasks and streamlined for optimal performance, ultimately reducing overall cost. [2]

Target Specifications

In order to provide CGI with a welder to meet and/or exceed their expectations, the proposed welder will meet the following specifications: the welder will be capable of performing complex, deep and thick 3-Dimensional welds. The welder's part size capabilities must be able to accomplish various weld complexities on at least small to medium sized parts, up to a length of 400mm long, which will be made from various metal materials. In order to provide precision welds, the welder will also be capable of securing the part with minimal human interaction. Although there are no specified size requirements, the size of the welder will be small enough to ensure there is no wasted floor space, but large enough to ensure no overheating occurs or down time is required during a continuous 8 hour work day for 5 days a week. [2]

Constraints and Limitations

Since the customer is designing a new robotic welding cell, which they did not have in the past, they do not have many limitations or constraints in the design. With that being said, there is a limited amount of information or direction as to how the customer would prefer the welding cell to operate. Our customer is dealing with information sensitive projects; therefore, the design of the welding cell has to be broad in order to be able to handle as many different materials as possible in a variety of shapes and sizes. This scope requirement is due to having no information on the material or sizes which the parts are to be made. The customer has also stated that they would like the welds to be able to encompass a variety of qualities and specifications in order to prevent limiting the welding cell's use. Weld specifications such as width, depth penetration, and weld quality should all be taken into consideration in order to accommodate as many different scenarios as possible. The wide variety of welds that are required will

limit the types of machines that can be purchased or designed. Due to the large scope of the welding machine, this will also increase the cost of the design due to the increased complexity of the welding cell. The customer has also requested that the welding cell be a turnkey operation. This limits the types of welding devices that can be used, due to the requirement of being controlled by a computer system. Further, the software that can be used will be required to accept drawings from a program, such as Unigraphics. The system can also be programmed manually by the system interface such as the iPendant. Therefore, the welding cell will be not be limited by products or designs that accept computer input and are able to receive, interpret and control the system via an imported drawing. [2]

Project Objectives

The objectives of this project are to research robotic welding cells, their operating systems and installation requirements and provide a bill of materials to allow for a turnkey automatic computer controlled robotic welding system to be installed at CGI. The robotic welding system must be able to weld small to medium sized parts composed of a variety of different materials. Due to the nature of the parts to be welded, another requirement of the system is to operate within very sensitive tolerances, and perform deep welds. A list of installation requirements is also to be included, as well as the assessed cell advantages. This robotic welding cell, along with knowing the system requirements and system outputs, will allow CGI to be able to bid on new projects which require robotic welding capabilities. [2]

Welding Cell Design Features

The welding cell selection criteria was specifically selected in order to meet the customers needs. This next section provides details of all the components of the selected Lincoln Electric 50 HP welding cell and how each component meets the customer's requirements. [1]

System 50 HP Platform

The System 50 HP platform is a welding cell, which contains dual Fanuc tilt/rotate positioners, dual pneumatic pop-up doors and a palletized base. The use of dual operating bays will help ensure continuous operation. That is, the robotic welding arm can be in operation in one bay while a technician unloads and reloads the idling bay. The size of each table is 42"x 36", which provides adequate room for small to medium sized parts. The use of pneumatic doors is a convenience and time saving measure for the operating technician and helps to provide a safe work environment. The palletized base allows for complete work cell portability. If the floor plans change in the future, the system can simply be unplugged, lifted and relocated to its new location. Lastly, the cell contains a rear access door for entry into the work cell for maintenance and cleaning. The access door will help provide a sensible downtime during servicing. The cell layout can be seen in the next section in the below figure which has a total floor footprint of 82" by 188". [1]

Welding Cell Drawing

The welding cell shown the below is the actual design of the welding cell that has been selected for use.

Figure 1 - 50 HP Welding Cell [1]

Fanuc Arcmate 100iC/6L Robot with R30iA A-cabinet controller

The Fanuc Arcmate 100iC/6l robotic arm combined with Lincoln Electric wire feeding modification is essential for quality welds. The wire feeding modification provided by Lincoln Electric allows the feeding wire to be feed through the base of the arm and outputted at the J3 axis (tip of the welding robotic arm). This allows reduction in weight inertia, ultimately providing a more stable arm for welding. Further, the modification is a more compact design and reduces the potential for the wire to be caught on surrounding objects. Furthermore, each axis of rotation on the robotic arm has its own independent set of brakes to ensure precise movement and improved quality welds. [1]

The robotic arm, which can be seen below, can be mounted to a variety of surfaces. That is, the arm can be mounted to the floor, mounting table, wall, or even the ceiling. This provides the potential to create a more compact environment should a complete welding cell be too large or become too large in the future after continuous improvement implementations. This provides Cormer Aerospace with the option to compact the cell layout or change their floor layout in the future. [1]

Figure 2 - Robotic Welding Arm [1]

Table I - ROBOTIC ARM CAPABILTIES [3]

Items		AM100*iC*	AM100*iC*/6L
Axes		6	6
Payload (kg)		10	6
Reach (mm)		1420	1632
Repeatability (mm)		±0.08	±0.1
Interference radius (mm)		262	262
Motion range (degrees)	J1	360	360
	J2	250	250
	J3	445	445
	J4	380	380
	J5	380 / 280(1)	380 / 280(1)
	J6	720 / 540(1)	720 / 540(1)
Motion speed (degrees/s)	J1	210	210
	J2	190	190
	J3	210	210
	J4	400	400
	J5	400	400
	J6	600	600
Wrist moments N-m (kgf-m)	J4	22 (2.2)	15.7 (1.6)
	J5	22 (2.2)	10.1 (1.0)
	J6	9.8 (1.0)	5.9 (0.6)
Wrist load inertia (kg-m²)	J4	.63	.63
	J5	.63	.38
	J6	.15	.061
Mechanical brakes		All axes	All axes
Mechanical weight (kg)		130	135
Mounting method(2)		Floor, ceiling, angle, and wall	Floor, ceiling, angle, and wall
Installation environment			
Temperature (°C)		0 to 45	0 to 45
Humidity		Normally: 75% or less Short term (within a month): 95% or less No condensation	
Vibration (m/s²)		4.9 or less	
Payload at axis 3 (kg)		12	12

Notes:
(1) J5 and J6 motion range when internal torch cable is installed.
(2) Motion range is de-rated for wall and angle mount.

The welding arm has a reach of 1.632 meters providing the flexibility to work in a dual-bay welding cell, with the robotic arm located in the center. Ultimately, the flexibility of the robotic arm allows for continuous operation provided that parts were loaded in the bay awaiting operation. [1]

The R30iA remote control box, which can be seen below, is equipped with a 7-meter cable allowing the unit to be at a fair distance away from the operating robotic arm. The 7-meter distance allows the

operator box to be on the external side of the welding cell providing obstruction free space for larger parts within the cell as well as more mobility of the welding arm. [1]

Figure 3 - Control System [1]

The integrated operator box [IOB] contains an emergency stop button that terminates the power at the instant that the button is depressed. This function can be considered as a safety requirement as well as the allowance to terminate the operation to salvage a part from less than ideal situations (i.e. if the weld is not progressing as required). [1]

The IOB also contains a cycle start and fault reset buttons. Further to the buttons, the IOB contains indication lights for the controller power and for fault indications. The indication lights will alert the operator that attention is required and will lower the un-necessary downtime. The IOB contains an hour meter which can be used for monitoring the requirements for servicing and/or to provide data for analytical purposes. [1]

Fanuc iPendant Interface

The Fanuc iPendant interface, which is shown below, comes with a 10-meter long cable connecting the IOB with the controller. This will allow the operator to be at a safe distance during operation and programming. The controller also has a user-customizable interface to allow for a more personalized and therefore, more efficient operation. [1]

Figure 4 - iPendant Interface [1]

Dual Fanuc Tilt Rotate Positioners

The Fanuc tilt/rotate positioners, which can be seen below, will provide a 2-axis rotating table that will work in conjunction with the robotic arm. This will allow the robotic welding arm to be in the optimal position for providing the highest quality welds. Furthermore, the positioners are capable of a payload capacity of 500kg for slightly larger parts. [1]

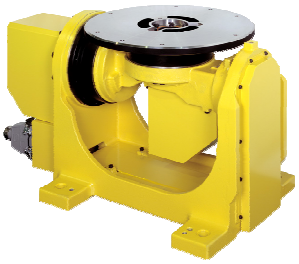

Figure 5 – Positioners [1]

Powerwavei400 Welding Power Source

The Powerwavei400 inverter, which can be seen below, is the power source for the welding process. The inverter works at a high frequency and therefore provides a higher quality weld. The efficiency of the Powerwavei400 is approximately 88-90% at a 95% minimum power output. Further, this inverter is capable of operating from a universal input voltage between 208 to 575 volts, which encompasses the input voltage of the System 50HP welding cell (480V or 575V). Lastly, the Power wavei400 can process any provided production monitoring in real time. [1]

Figure 6 - Powerwave Inverter System [1]

Power Ream Torch Tending Station

The power ream torch tending station, which is shown below, is an automatic cleaning station, which cleans the torch tip of splatter build up. This cleaning station is a simple push-button pre-programmed operation. That is, once the program is turned on, the torch will automatically go to the cleaning station after a pre-determined amount of operational time. Should the torch tip have excessive splatter build up, the cleaning station will recognize this and accomplish the cleaning process. [1]

Figure 7 - Automatic Torch Tending Station [1]

The cleaning process is short and precise. The main advantage to the automated cleaning station is that the wire length will be cut at same length every time providing constant and continuous welds. The ease of maintaining the cleaner is quick and easy as well as easy-to-replace parts. [1]

Cool Arc 40 Water Cooling System andRoboticISTMWH455 Water-cooled Torch

A water-cooled torch, which can be seen below, is ideal for continuous operation of a robotic welding system. The cables connecting the torch are highly torsion resistant in the 6th axis. High flexibility allows the torch to become accessible to the working piece. The torch also provides safe and optimal performance through high repeatability and therefore, increases quality and reliability. [1]

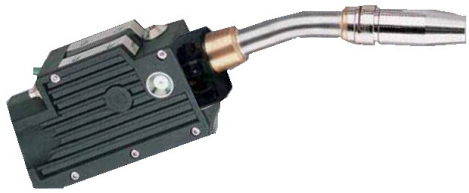

Figure 8 - Water Cooled Torch [1]

Wire Feeding System

The Autodrive 4R220 wire feeder, which can be seen in the figure below, is digitally controlled by the power wave power source allowing for both items to be in sync. The tachometer feedback provides calibration and precise control of the wire feeding speed. The feeder can brake from maximum speed to zero in milliseconds, which minimizes the chance of the wire sticking to the puddle and ultimately requiring un-necessary human assistance. The wire feeder is self-feeding and therefore minimizes the required human intervention. [1]

Figure 9 - Wire Feeding System [1]

Fume Extraction Hood

A fume extraction hood ensures that the harmful gases created by the welding process do not enter the air and is consequently inhaled by nearby workers. This option should be considered if the welding cell is to be located in a non-well ventilated area on the shop floor. The system consists of a Sheet metal hood sized for the robotic cell and a 10HP, 575 V Extractor Fan Statiflex 6000 self-cleaning filter system. The fan will operate only when the robot is on, and the filter cleans itself when it is programmed for, typically, after hours or on breaks. This is a smart system, needing attention only when the dust bin is full. [1]

Welding Process

Many welding processes were considered including Cold Metal Transfer [CMT], Gas Metal Arc Welding [GMAW] and Laser-GMAW hybrid. GMAW was ultimately chosen as it meets and exceeds the customer

needs while keeping the cost low. Further, the process the welding system can handle is easily upgradeable to the CMT and/or Laser hybrid process if the customer determines that their needs have increased. To upgrade to the CMT system, the customer must purchase the Fronius CMT inverter. To upgrade to the laser hybrid process, the customer must purchase a larger welding cell and all of the robotic laser welding items. [4][5][6]

Cold Metal Transfer

Cold metal transfer welding is a new type of welding process which uses deliberate and alternating discontinuing of the arc in order to provide a hot-cold sequence during welding, which significantly reduces the arc pressure. It should be noted that the welding process is not actually cold, but rather cold compared to most other welding processes. This process is specifically designed for robotic welding due to the high precision of the process and cannot be controlled by a human technician. The main advantages to this type of welding are: Due to the lower temperature, there are less temperature effects on the material being welded such as warpage and therefore results in a higher precision in the welding process. Further, due to the lower temperature of the welding being performed, there is little to no splatter from the welding process. This not only decreases the wasted material but also provides a cleaner finished product with less after welding touch ups being required. [5]

Gas Metal Arc Welding

Gas metal arc welding is also known as metal inert gas welding. GMAW uses the filler rod to transfer the current and is consumed during the welding procedure. This rod then becomes part of the part being welded. This method also uses an inert gas to shield the weld area. The main advantages to this method are that welding can occur at a fast rate and be accomplished both by a robotic welder and manually by a human technician. Also, welds can be accomplished in all positions in many different orientations. [4]

Laser Hybrid Welding

Laser hybrid welding combines the deep weld penetration of laser welding and the superior gap tolerances of GMAW. It is possible to accomplish deep and wide welds in a single pass where as if the components were individualized, the laser beam welding would have a difficult time accomplishing the task and GMAW would require several layers of welds. The cost of implementing the laser-GMAW hybrid system is very costly at the initial setup and requires much larger floor space. [6]

Operation

When dealing with a complex and sophisticated welding cell, the system will also have complex and sophisticated programs to ensure that they operate accurately as required. These processes will be outlined in the following section.

Maintenance

It is important to keep the robotic welding cell free of dust and debris. Dust may enter the controller or power supply and block ventilation causing them to overheat. Further, the arm must be cleaned and maintained on a regular basis in order to maintain accuracy and to function as required.

Safety

It is important that the robot's operator is always observing where the robot is positioned and that the program that it is running. These robots can move at a very fast speed and carry a lot of momentum. If the operator is unaware of the robots position or movement locations within the cell, it is possible that the robot may impact the operator or other objects with in the cell damaging them or causing serious injury. It is critical that the welding cell be setup to operate safely. Some additional safety features may be added to the work cell to provide a less hazardous environment. These features include: safety fences or barriers, light curtains and pressure mats. [1][7]

Weld Cell Safety Features

One safety feature that can be included in the weld cell is safety barriers. Safety barriers work by only allowing the robot to run when the barrier is closed. If the barrier is open, it will not allow the robot to operate. Another safety feature is the light curtain. Light curtains operate by using a beam of light pointing at a sensor on the opposite side of the cell. When an object or person enters the cell, the connection between the light source and the sensor is broken, and triggers the robot to come to a halt. To restart the robot again, the operator must clear the obstruction and manually start running the program again. Pressure mats are mats with weight sensors inside that are triggered when the operator is standing on the mat. When the operator steps off the mat, it breaks the connection to the robot and must be reset to operate again. In order to maintain safety, the subject welding cell has been equipped with automatic closing doors. [1][7]

Teach Pendant Safety Features

One safety feature built in to the teach pendant is called the Deadman Grips. The Deadman Grips are two 3-position switches located on the underside of the teach pendant. The three positions are open, half depressed and fully depressed. In order for the robot to operate during programming, the Deadman grips must be depressed half way. If the Deadman grip is fully open or fully depressed, the program stops and the robot comes to a halt. This safety feature is used because the operator may react differently when he encounters a panic situation. Some people have a tendency to let go of the pendant while others are more inclined to squeeze the pendant. In both of these cases the Deadman grips will trigger the robot to stop. [1][7]

Another feature built in to the teach pendant is the emergency stop button, a large red button on the front face of the teach pendant. This is a failsafe button used when all other options have failed. It disconnects the robot from the power source and resets the system. [1][7]

Programming

It is important that the operator be well trained and has experience in welding operations as well as robotic programming. The robotic welder is a powerful tool and can greatly increase production, but it can only weld successfully with the proper welding inputs from the operator. The robot will move and function exactly as it is told, and as such, it relies on the operator to input the speed of the robot among other inputs to produce a quality weld. [7]

Figure 10 below shows a simple welding program, for welding a straight line on the corner of a box. The far left numbers 1 through 6 represent the lines of the program with a command on each line. There are two types of ways the robot can move from point to point, the first is linear movement. This is when the robot will move in a straight line from one point to the next. Linear movement is represented by an L, as seen in Figure 10 after the colon. The second way the robot can move from point to point is called joint movement. The "@" symbol before the P is used to symbolize the home position. It is not required to start and end the program from the home position, however it is recommended. The location in space, or the point in space the robot is programmed to go to is represented by "P [ ]", with the referenced point number in the brackets. As can be seen in the program in Figure 10, the home point is represented by "P [1]". It can be seen that that this point is called on twice in the program, once at the beginning, and again at the end of the program to return it to that initial home position. Following the point in space is a number. This number represents the speed at which the robot is moving in-between points. In the case of the program seen in Figure 10, for the movement between points 1, 2, and 3, and again between points 5 and back to 1, the robot is moving at a speed of 2000.0 inches per minute. From point 4, the robot is moving at 100.0 inches per minute to the destination point 5. The pendant allows the user to change the units of speed to the user's preference. The robot is slowed down at point 4, as this is where the robot reaches the first corner to weld on the box. The robots speed is decreased to

provide a better weld, as faster movement will not allow the metal to pool. The speed at which the robot welds is set by the user, using the operator's knowledge of welding. There is no preset speed for the welds as it is dependent on many different variable factors. Although a welding arc start command for the robot is not seen in this program, it would be located at point 4. The arc start command tells the robot to initiate the welding process. The robot will continue welding between points until it is commanded to stop. The "Arc stop" command is used to end the welding process. "CNT" followed by a number tells the robot to move in a continuous motion at the rate specified by the operator. The other option is "FINE" movement which moves in short increments. The end of the program is symbolized by the line "[End]". This tells the program to stop running as it is the end of all processes. [7]

When programming the robot, it is more desirable to change the speed at which the robot moves. By slowing down the robot's movement speed, it allows the operator to more finely tune the robot. This is crucial when approaching objects because if the movement speed is to fast or coarse, the robot may collide with the part. If the movement is too fine it will take a long time for the robot to reach its destination. This setting is called "%RAPID" and can been seen as the number in the green box in the top right corner of the teach pendant. It can be any integer value between 1% and 100%. Common values used are 5%, 25%, 50% and 100%. [7]

Depending on the model of robot and the applications it is used for, it may have up to 6 axes. Each of these axes can be controlled with the teach pendant to move the robot. This can be seen in Figure 10 in the bottom right corner and the buttons are labelled –X, +X, -Y, +Y, etc. Each axis has a "–" and a "+" button. This allows the operator to jog the robot in the two directions of the axes. [7]

When the operator is testing a program, it is recommended to run the program with step function on. This function allows the user to run the program one line of code at a time, instead of the robot running through the entire program. By running the program one line at a time, the operator can see how the

program functions and can make adjustments accordingly before the entire program runs. When the operator feels the program can run successfully the step function can be removed and the program can run with smoothly. [7]

Another useful command is the circle command. This allows the operator to program the robot to move or weld in a semi- circular motion. First, the operator sets the initial point of the circle command. The second point the operator sets the middle of the semi-circle. To create a circular motion, the operator will repeat the process after the first. [7]

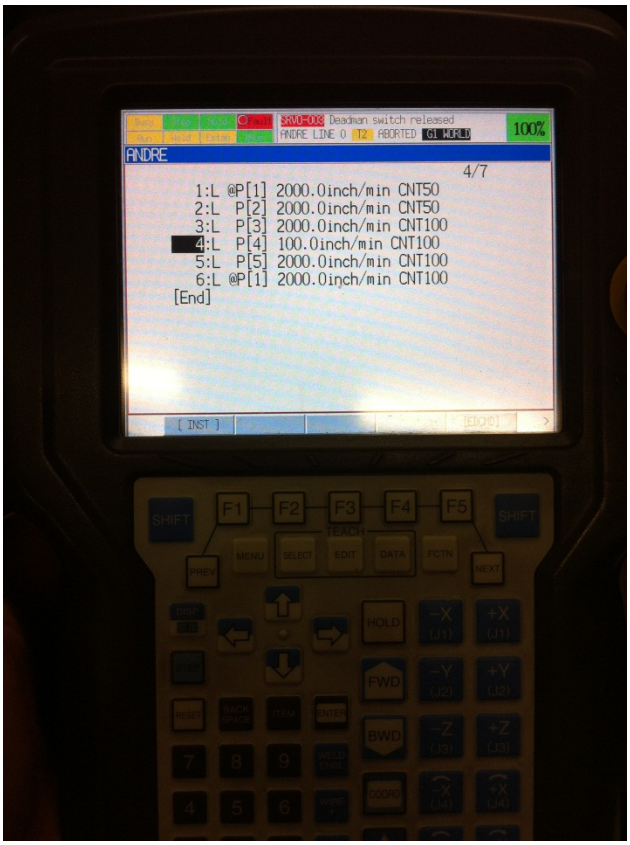

Figure 10 - Simple Program on Teach Pendant

After the robot has been programmed, operation is as simple as the operator loading the part into the tool jig correctly and running the appropriate program. [7]

Off Line Programming

Another method for programming a robotic welder is called off line programming. It is called offline because it takes place on a computer away from the robotic welder and controller. It uses the network connection to allow the program to be transferred to the robotic welder via Ethernet. Examples of this software include ArcWeld, RobotStudio and RoboCAD. Offline welding software uses the same principals as the pendant to program the robot, however due to the increased capabilities of a full computer, offline programming has the ability to incorporate CAD geometries and render 3D models. The user can simply import a 3D model of the part and set the weld start and end points, and then the robot will automatically generate the weld path. Popular formats that the user may import into the welding software are ".dwg" files. Features such as collision detectors provide the operator the security that the part will not interfere with the robots path. Offline programming provides a much faster approach to programming the robotic welder and is a perfect solution for programming if the operator does not have access to the robot and pendant itself. However, this option reduces the operators control over the program, which may lead to less precise welds. [8]

Overall Cost

There are many factors that need to be considered when calculating the overall cost of the welding cell, such as welding material and process costs, cell costs, and installation costs.

Welding Material and Process Costs

The main advantage to using a robotic welding system is lowering the labour and overhead involved with the welding process. Since you only require a single technician to operate a robotic welding cell and since his only function is to load and unload the system, the welding process becomes much more efficient. On the other hand, with a manual robotic welding cell, the technician has to do all the part setup at which time no welding is being accomplished. Therefore, this is considered wasted time since no arc is active. For a robotic welding cell, once the system has been started, it will continually weld, while the technician loads the 2nd table, which is not in use by the robotic welding system. This allows the systems to work continuously and reduce the time when there is no welding occurring. [9][10]

Secondly, the amount of gas and electrode used by a robotic welding system is lower compared to a human welder. This is due to the welding systems automated controls that know exactly when to start the gas and when to shut it off. With a human welder, there is a little more uncertainty and therefore a little more waste. Also, the welding cell automatically trims the wire in the welder the same every time to reduce waste. A human welder is required to extend the wire out of the torch to be able to trim the excess wire. Again, this is a waste of product and adds up over time. [9][10]

The below table shows how the efficiencies increase in every category (Labour, Electrode use and Gas) when the welding is being done by a robot instead of a human. Therefore, this shows that over time the robotic welding system will save the customer money. [9][10]

Table II - WELD COST ANALYSIS [9] [10]

Cost per hundred feet of weld		Proposed Method Robotic Pulsed GMAW system	Present Method Semiautomatic GMAW	Difference
Labor & Overhead	$ / 100 ft	27.57	102.04	-74.47
Electrode	$ / 100 ft	4.03	5.24	-1.21
Gas	$ / 100 ft	1.13	1.71	-0.58
Total	$ / 100 ft	32.73	108.99	-76.26
Return on Investment of a New Robotic Welding System		**25.41 Weeks (based on a 40 hour work week)**		

Further, the next table shows the savings per hundred pounds of filler material when comparing time on arc and gas usage of a manual process compared to a robotic welding process. This will give the customer an idea of the savings that can be obtained from using the robotic system in lieu of a human for welding. [7][9][10]

Table III - SAVINGS PER HUNDRED POUNDS OF FILLED MATERIAL [7]

Savings per a hundred pounds of filled material ($/lb)		
Manual process	Arc on time (Utilization of equipment)	20%
Robotic process	Arc on time (Utilization of equipment)	70%
Labor cost	$/h	$50.00
Deposition rate	lb/h (pound of filled material per hour)	10.00
Filler metal	$/lb (dollar per pound of filled material)	$1.75
Shield gas	$/lb (dollar per pound of filled material)	$0.88
Manual process	$/ 100 lb (dollar per a hundred pounds of filled material)	$3,812.50
Robotic process	$/ 100 lb (dollar per a hundred pounds of filled material)	$1,089.29
Max Savings*	% (percentage of cost reduction)	71.43%

For an in-depth look at how to calculate welding costs, including filler material required, gas usage, electricity usage and how the below table was proven, please see Appendix C.

Bill of Materials and Financial Details

The main components of the system are:

- The Robotic Arm
- The two 2-axis Positioners
- The Controller Interface
- The Source
- The Feeder
- The Water-cooled Torch
- The Water Cooling System
- The Welding Cell External Shell

All of the above is included in the estimated total cost of the cell at a price of $223,170.00. Components description and cost details can be found in the appendix. [1] [7]

Further to the above items, the following components are not part of the welding cell mentioned above but C.A.D.D. Consulting feels that the following components should also be purchased:

- Power Ream Torch Tending Station
- Coordinated Motion Software

- TAST Software
- Touch Sensing Software
- Fume Extraction System

These options combined come to a total cost of $39,830.00. [1] [7]

Shipping

The current shipping cost from the supplier's location in Ontario to the customer location in Manitoba is $4,000.00, with an additional charge of $1,000.00 for a 4,000-pound capacity forklift rental (in the case the customer does not have one in the site). [1] [7]

Training

The cost estimation of the first training is $3,000.00. It's extremely recommended by the supplier to send operators to be trained in the training center in Ontario. [1] [7]

Electrical Setup

The electrical setup can be done by the customer's plant electrician or millwright and the overall cost is estimated at $1,000.00 (depending on the current plant setup). [1] [7]

Final Cost

Therefore, with all the information provided, the total cost of the recommended welding cell will be $273,000.00. This includes the base cell package, all the recommended options, delivery, installation and the electrical hook-up cost. (See appendix for complete quote) [1] [7]

Conclusion

In conclusion, the sourced robotic welding system will be able to not only meet all of CGI's current needs, but exceeds the customer's needs in multiple categories. The proposed welding cell will be able to handle 3-Dimensional non-linear welds on parts up to the required length of at least 400mm, due to the 6 axes extendable robotic welding arm and the two axes tables contained within the welding system. The welder is also be capable of performing thick and deep welds due to the capability of the welding system to be able to handle multiple different wire thicknesses, both small and large diameter, in the automatic wire feeding system, combined with the water cooling system integrated into the robotic arm to prevent overheating. Also, as requested by CGI, the sourced welding system can also handle a variety of different materials with only minor adjustments to the system. Finally, as requested by CGI, the system that was sourced will be a turnkey system and will be ready to start welding without requiring further components to be sourced. [1][2][7]

The required cell will contain all the components and will cost $273 000 as broken down below in Table IV. [1] [7]

Therefore, the sourced welding cell meets all of our customer's current needs as well as being able to be extended to also handle their possible future needs as well. (See appendix for complete quote) [1] [7]

Table IV - TOTAL COST OF REQUIRED WELDING SYSTEM [1] [7]

Total Cost			
QTY	Component	Cost (USD)	Total Cost (USD)
1	Fanuc Arcmate 100iC/6L Robot w/ R30iA a-cabinet controller	-	
1	Fanuc iPENDANT™ Interface	-	
1	Torch Guard Software	-	
1	Torchmate II Block	-	
1	Constant Path Software	-	
1	PMC Software	-	
2	Integrated Servo Driven 2-Axis Positioners	-	
1	Fanuc Safety Local Stop Package	-	
1	POWERWAVE® i400 Welding Package	-	
1	Auto drive 4R220 Wire Feeder	-	
1	Robotic iSTM Water-cooled Torch (WH455)	-	
1	System 50HP Platform	-	
1	Control Panel	-	
		$224,170.00	
1	Power Ream Torch Tending Station	$3,950.00	
1	Coordinated Motion Software	$2,200.00	
1	TAST Software	$5,000.00	
1	Touch Sensing Software	$4,000.00	
1	Fume Extraction System	$24,680.00	
	Shipping	$4000.00	
	Forklift Rental	$1000.00	
	Training	$3000.00	
	Electrical Setup	$1000.00	
			$273,000.00

Work Cited

[1] S. Trembley. “Robotic System Quote”. Personal E-mail (29-Nov-11) Attachment: System 50HP quote (See appendix)

[2] J. Bisharat. Interview on customer needs and requirements. Cormer Aerospace, Winnipeg, Manitoba. 23-Sept-11.

[3] FANUC Robotics. “ARC Mate 100iC and 100iC/6l”. www.Fanucrobotics.com 2 12 2011

[4] ESAB. “Mig/MAG or GMAW”. Internet: www.esab.se/global/en/education/processes-mig-gmaw.cfm. 25 10 2011.

[5] R. Worx. “Welding Application – Cold Metal Transfer”. Internet: www.welding-robots.com/applications.php?app=cold+metal+transfer 25 10 2011

[6] Engineers Edge. “Laser Welding Review”. Internet: www.engineersedge.com/manufacuring/laser_welding.htm 25 10 2011

[7] S. Trembley. Interview and training on Lincoln Electric Welding Cells. Lincoln Electric, Winnipeg, Manitoba. 24-Oct-11.

[8] Metal Forming Magazine (01 02 2009). “Robotic Welding Efficiency. Magazine. Available: www.archive.metalformingmagazine.com/2009/02/roboticwelding.pdf (2 12 2011)

[9] D. Miller. “Determining the Cost of Welding”. Website: http://weldingdesign.com/processes/news/wdf_10760/ (03 01 2011) Welding Design and fabrication.

[10] Modern Machining Company. “Advantages of Robotic Welding”. Internet: www.modernmachinerycompany.com/index.php/manufacturing/advantages-of-robotic-welding/ (05 12 2011)

Appendix A

LINCOLN ELECTRIC COMPANY OF CANADA LIMITED

939 Gana Court,
MISSISSAUGA, ONTARIO
L5S 1N9
Phone (905) 565-5600
Fax (905) 565-5599
www.lincolnelectric.ca

November 29, 2011

Subject: Quotation Number LIST PRICE BUDGETARY – System 50HP for robotic arc welding cell

Dear SIR,

Thank you for your inquiry. Lincoln Electric Canada Automation is pleased to present a quotation for a robotic Gas Metal Arc Welding solution to Roboweld Inc. We have quoted a Lincoln Electric System 50HP cell for this application.

Lincoln Electric Custom System 50HP Cell Features:

- Palletized base for drop-in-place installation, simple to set up, easy to operate
- Side-by-side two station design to minimize operator walking distance
- Dual servo positioners integrated with the robot controller for infinite control of the positioning and speed
- Powered roll-down door with light curtain along the floor to maximize safety
- Handles multiple part numbers simultaneously.
- Redundant safety circuits
- Integrated user interface.
- High speed digital communication featuring Arclink™.
- Integrated Safety Local Stop Unit

We look forward to working with you on this project. If you have any questions or need additional information, please call us at 905-565-5600.

Sincerely

Sebastien Tremblay

Technical Sales Representative

Lincoln Electric of Canada
939 Gana Court, Mississauga, ON L5S 1N9
Tel: (905) 565-5600, Fax: (905) 565-5599

QUOTATION

Quote No.	Sample
Date	November 29th, 2011
Customer	
Attention	
Phone	
Fax/E-mail	

System Description

The proposed custom system is a flexible two-station robotic cell designed for welding and cutting applications. The workcell is able to handle parts that require positioning in two axis during the weld cycle. The layout is designed to minimize operator walking distance for higher efficiency, and is ideal for flexible manufacturing systems allowing manufacturers to handle multiple part numbers simultaneously. The workcell enclosure provides a complete cell barrier with a solid sheet metal weld flash. This cell is configured with an integrated palm station complete with operator controls.

Lincoln Electric understands that the customer will provide the fixtures for the proposed system. We assume that customer-designed and customer built welding fixtures will not exceed the capacity of proposed equipment

Project Objectives

- Eliminate manual welding operation to reduce overall welding labor costs
- Increase the production rate with consistent quality
- Provide a Lincoln Electric standard, compact welding cell

Lincoln Electric of Canada
939 Gana Court, Mississauga, ON L5S 1N9
Tel: (905) 565-5600, Fax: (905) 565-5599

QUOTATION

Quote No.	Sample
Date	November 29th, 2011
Customer	
Attention	
Phone	
Fax/E-mail	

SYSTEM 50HP

COMPLETE ROBOTIC WORKING CELL

FOR QUOTING PURPOSE ONLY

FINAL PRODUCTS AND DIEMNSUIONS MAY NOT BE EXACTLY SAME AS SHOWN

Lincoln Electric of Canada
939 Gana Court, Mississauga, ON L5S 1N9
Tel: (905) 565-5600, Fax: (905) 565-5599

Operation Sequence

After the machine is turned on, the following sequences will happen

1. The operator will load the part into the fixture on Side A and close the clamps
2. The operator steps out of the cell and press the CYCLE START button. At this time the safety light curtain will be active at Side A and operator is not allowed to enter the zone.
3. The roll-down door on side A comes down and activates a dual limit switches.
4. After the door is closed completely, the robot selects the program A and then starts welding the part on side A
5. While robot is welding on side A, the door on side B is open and the operator can step in, release the clamps, unload the welded part, load another part and press the CYCLE START button.
6. When the robot finishes welding on Side A, it goes to weld the part on Side B.
7. Now, the roll-down goes up and the light curtain will be inactive at side A; the operator can enter this zone again and remove the finished part.
8. These sequences will be repeated until operator wants to stop the machine

Lincoln Electric of Canada
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Tel: (905) 565-5600, Fax: (905) 565-5599

QUOTATION

Quote No.	Sample
Date	November 29th, 2011
Customer	
Attention	
Phone	
Fax/E-mail	

Project Scope of Supply

QTY	ITEM DESCRIPTION

1 **FANUC ARCMATE 100iC/6L ROBOT w/ R30iA a-cabinet controller**

(6 kg Maximum Payload, Floor, Wall, or Ceiling Mounted, 1.632 m Reach) with:

- Brakes on all axes
- Lifting eye bolts
- Integrated Lincoln Electric wire feed control cable, input at base, output at J3 axis
- 2 Integral air lines, 1/4"' NPT, 1 gas and 1 air connection port as base with 2 outlet ports at J3
- EE (5 pin) Connector at J3 axis with 1 input, 1 output, handbroken, +24 VDC and 0 VDC

Remote R-30iA Controller with:

- 2 Slot Backplane including 2 mini-slots and 1 wide mini-slot
- Main CPU Board with:
  - Multiple Processors for Robot and Communication Operation
  - (2) Built-in 100 BaseTX/10 Ethernet Ports with RJ-45 connector
  - PCMCIA Interface Port
  - 64 Mb FROM
  - 64 Mb DRAM
  - 3 Mb SRAM
- Controller Power Supply
- 6 Channel Servo Amplifier
- 3.0KVA Power Transformer for 380 - 575 VAC
- 7 meter Robot Connection Cables
- RIA-compliant Category-4 Dual Channel Safety (DCS) Unit

Integrated Operator Box with:

- Circuit Breaker for 380 - 500 VAC
- Emergency Stop, Cycle Start, and Fault Reset buttons
- Indicator lights for Controller Power and Fault
- Hour Meter
- RS-232 port
- USB Interface Port
- T1/T2/Auto Mode Selection Switch
- Standard Arc Welding Documentation
- Standard Documentation

QTY	ITEM DESCRIPTION

QUOTATION

Quote No.	Sample
Date	November 29th, 2011
Customer	
Attention	
Phone	
Fax/E-mail	

Lincoln Electric of Canada
939 Gana Court, Mississauga, ON L5S 1N9
Tel: (905) 565-5600, Fax: (905) 565-5599

1 **FANUC iPENDANT™ INTERFACE**

- Standard iPendant with multi window with 10 meter cable
- Ergonomically-designed and color pendant
- 6.4" color TFT backlit LCD display
- Lightweight 1.25 kg
- Integrated help and diagnostics
- User-customizable interface

1 **TORCH GUARD SOFTWARE**
This software includes: Collision Guard, Torch Mate 3, and Payload ID

- The Collision Guard option provides a highly sensitive method to detect that the robot has collided with an object and then stops the robot immediately. This helps to minimize the potential for damage to the end-of-arm tooling (EOAT) and robot. Collision Guard also helps to prevent damage during teaching.

- The TorchMate option provides a cost effective, easy-to-use solution for automatic adjustment of the Tool Center Point (TCP). TorchMate 3 automatically compensates for bent torch barrels and worn contact tips to reduce weld defects and increase system productivity. The torch Mate block can be purchased separately

- The Payload ID identifies up to ten wrist payloads by moving axes 5 and 6 while monitoring torque. Automatically determines payload's mass, center of gravity and Inertia values. Warns user of robot overload condition.

1 **TORCHMATE II BLOCK**
- The Torch Mate block can be used with Torch Guard or Torch Mate software.

1 **CONSTANT PATH SOFTWARE**
- Robot maintains constant motion path, regardless of velocity override.

1 **PMC SOFTWARE**
Provides Ladder Logic Control capability in R-J3 Controller. Ladder logic programming is done on a PC with the help of FAPT III software.

QUOTATION

Lincoln Electric of Canada
939 Gana Court, Mississauga, ON L5S 1N9
Tel: (905) 565-5600, Fax: (905) 565-5599

Quote No.	Sample
Date	November 29th, 2011
Customer	
Attention	
Phone	
Fax/E-mail	

QTY	ITEM DESCRIPTION
2	**INTEGRATED SERVO DRIVEN 2-AXIS POSITIONER** Integrated servo driven 2-axis positioner ▪ Fastest positioner in it's class. ▪ Multiple mounting positions. ▪ Integrated Welding Ground ▪ Local Stop enables safe and easy operator interface ▪ Factory installed motor covers ▪ Tapped holes for Lifting hardware ▪ Dowel pin locations for fixture repeatability ▪ Payload Capacity : 500 kg (1100 lbs) ▪ Motion Range :J1Axis: 270° (-135° to +135°) J2 Axis: 480° (-240° to +240°) ▪ Motion Speed: J1 Axis: 120°/sec J2 Axis: 190°/sec
1	**FANUC SAFETY LOCAL STOP PACKAGE** Includes Local Stop PKG. (2 group) used for two independent motors. LSU hardware mounts in aux axis cabinet.
1	**POWERWAVE® i400 WELDING PACKAGE** ▪ The Power Wave® i400 & AutoDrive™ 4R90 solution delivers Lincoln's best performance technologies and welding processes all rolled into one highly efficient inverter power source paired with a compact, durable wire feeder designed for high-end robotic welding. ▪ Designed for simple, seamless integration with the FANUC® Robotics R-30iA Controller. ▪ Lincoln's Waveform Control Technology® gives you the ability to select the right waveform for each application – that means the arc has been optimized for each wire type and size for exceptionally smooth arc performance. ▪ High speed digital communication via ArcLink® protocol, a CAN connection or now the ArcLink® XT™. ▪ Best in Class Power - 10-420 amps output delivers the power you need for a wide range of processes and materials, with no derating for pulse waveforms. ▪ A Power Wave inverter operates at a high efficiency (88-90%) with a 95% minimum power factor (at rated output) and is capable of operating from a universal input voltage (208 to 575 volts)
1	**AUTODRIVE 4R220 WIRE FEEDER** ▪ Digitally controlled by the Power Wave power source ▪ Utilizes Arc Link, the leading digital communications protocol ▪ Tachometer feedback provides calibration and precise control of wire feed speed ▪ Feeder brakes from maximum speed to zero in milliseconds, minimizing the chance of wire sticking in the puddle

- Split wire guides provide trouble-free feeding and offer fast, tool-less wire installation, changeover and maintenance
- Easy-to-read gauge for accurate drive roll tension
- Brass-to-brass connections for good connectivity between feeder
- Self loading wire feature for easy set-up
- Package includes AutoDrive 4R220 Wire Feeder, Control Cable 25ft, Robotic Cable Adapter 2ft

1 **ROBOTIC iSTM WATERCOOLED TORCH (WH455)**

- *i*STM – the robot mount for the latest generation of welding robots with a central guided cable assembly through the 6th axis offers a high level of safety & flexibility.
- Highly torsion resistant cable assembly rotatable in the 6th axis over 480° (+/- 240°)
- Safety & optimal system performance due to high repeatability
- High productivity & long life time through rugged, simple design
- High flexibility and optimal work piece accessibility
- Reduction of maintenance costs due to an easy assembly and handling
- Highest reliability is offered through the comprehensive protection against dust and spatters

Rating; 450 amp CO2 , 400 amp mixed gasses, 100% Duty Cycle

1 **SYSTEM 50HP PLATFORM**

Complete *System 50HP* package includes:
Palletized Base for Complete Work Cell Portability,
Complete Robot Riser and Safety Enclosure With Tubular Framework and Sheet Metal Skin for Arc Flash Protection
Automatic electrical roll-down doors
Access Door for Maintenance, Torch Utility, Programming, Wire Drive Roll Kit Change out, etc
Positioner Axes, Gear Boxes, Mounting Plates, Tailstock Bearing
Horizontal Mounted Safety Light Curtain on the Loading/Unloading Zone

1 **CONTROL PANEL**

Integrated complete system control with robot logic. This control system consists of all safety devices and control enclosure wired and integrated into system. It includes integrated Operator Palm stations, safety relays, system programs and documentation.
No tooling control is included in this quote.

TOTAL SYSTEM PRICE: **$ 223,170.00 USD**

QUOTATION

Lincoln Electric of Canada
939 Gana Court, Mississauga, ON L5S 1N9
Tel: (905) 565-5600, Fax: (905) 565-5599

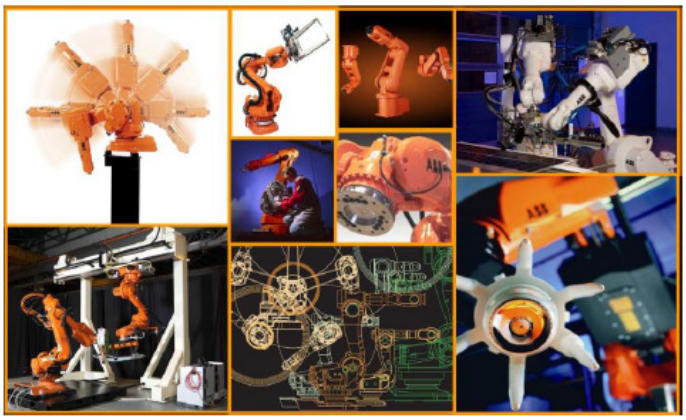
Quote No.	Sample
Date	November 29th, 2011
Customer	
Attention	
Phone	
Fax/E-mail	

RECOMMENDED OPTIONS (NOT INCLUDED IN THE TOTAL PRICE)

QTY	ITEM DESCRIPTION	
1	**POWER REAM TORCH TENDING STATION** ▪ Unique reamer with automatic retry feature. It detects when excessive spatter builds up, preventing the reamer from fully extending into the nozzle. When this occurs, the reamer retracts and automatically retries ▪ Simple pushbutton "No Error" programming technique ▪ Diamond-shaped clamp design provides a positive, self-centering grip on all nozzle sizes ▪ Easy configuration of Input and output and simple integration to all makes and models of robot systems ▪ On-board diagnostic indicator lights and error codes for trouble-free setup, fast maintenance, and easy replacement of standard components ▪ One year warranty on parts and labor ▪ Standard integrated wire clipper provides consistent wire stick out and removes the ball end of the welding wire to provide superior arc starting performance for .030"- 1/16"" (0.8-1.6mm) solid wires ▪ The package includes Reaming Station, Spray System, Wire Cutter and 20 ft. (6.0m) Input Cable	$ 3,950.00 USD 
1	**COORDINATED MOTION SOFTWARE** Coordinated motion simplifies setup and reduces expense when applying auxiliary axis positioners. The Coordinated Jogging feature allows quick program creation by enabling the programmer to jog the robot and positioner simultaneously, maintaining relative gun angles and stand-off distances. Weld travel speed remains constant while the robot moves in conjunction with the auxiliary axis.	$ 2,200.00 USD
1	**TAST SOFTWARE** Through Arc Seam Tracking (TAST), automatically adjusts the robot's vertical and lateral trajectory to compensate for part warping or misplacement.	$ 5,000.00 USD
1	**TOUCH SENSING SOFTWARE** Touch Sensing allows the robot to change a path automatically to compensate for object displacement. Note: Requires Constant Path	$ 4,000.00 USD
1	**FUME EXTRACTION SYSTEM** The system consists of a Sheet metal hood sized for the robotic cell, a 10HP, 575 V Extractor Fan Statiflex 6000 self-cleaning filter system. The fan will operate only when the robot is, the filter cleans when it is programmed for, typically, after hours or on breaks. This is a smart system, needing attention only when the dust bin is full. The filter acts as a silencer, attenuating the noise from the fan. The system includes a pre separator.	$ 24,680.00 USD

Appendix B

PROPOSAL



PREPARED FOR
UNIVERSITY OF MANITOBA

	PROPOSAL REFERENCE **#Q11-0506** Date: **November 25, 2011** Attention: Mr. Denis Silva	

November 25, 2011

University of Manitoba
Winnipeg, Manitoba
Phone: 204-451-3137
Email:umsilva4@cc.umanitoba.ca
Attention: Mr. Denis Silva

Subject: Q11 0506 University of Manitoba FlexArc® R 300

Dear Mr. Silva,

Thank you for contacting ABB for your automation service needs. We are pleased to have the opportunity to provide you with this *budgetary* proposal for a FlexArc® R-300 Single system.

With over 170,000 robot systems installed worldwide and thousands of complete automation systems, ABB is the largest automation system provider to the automotive and manufacturing industries.

ABB offers a complete range of robots and software products designed to meet any manufacturing goal --- offering lower operating costs, higher quality, more efficient employment of human resources, higher returns, and optimum use of valuable floor space.

ABB also provides dedicated customer service for every automation investment. Our comprehensive portfolio embraces the full range of services from maintenance and training, to process consulting and equipment reconditioning.

If you have any questions or concerns, feel free to contact us. We appreciate your business and look forward to working with you on this project in the upcoming weeks.

Sincerely,

George Paton
Channel Partner Manager- Robotics
Account Manager, Western Canada
ABB Inc.
Tel. 905-460-3420
Mobile: 519-320-1484

Nick McDonald
Business Development
ABB Inc.
Tel. 905-460-3465
Mobile: 416-522-3579

1.0 PROPOSED EQUIPMENT & SERVICES DESCRIPTION

1.1 FlexArc Single IRB1600ID R-300 Cell

Standard features of FlexArc® systems:

- Pre-engineered cell designs
- Variety of cell configurations to meet a customers specific requirements
- Self contained modular design allows for easy transport and minimum set up
- Palletized cells
- Minimize required floor space
- Typically robot, positioner, controller and welder are all contained on one pallet
- Standard torch service window to reduce torch maintenance time
- Fencing with arc flash protection
- Complete safety package
- Optional equipment available

Item	Qty	Description	Picture
1.	1	***IRB 1600ID IRB 1600ID-4/1.5 4 kg 1.5 m Robot*, with the following hardware and Software options:** 435-X IRB 1600ID -4/1.5 209-1 ABB orange standard 287-4 Standard 334-1 ABB 213-1 Safety Lamp 28-1 Axis 1-work range Limits. 700-3 Single cabinet 429-1 UL/CSA 769-4 3x480V 752-1 Cable gland 742-1 Rotary switch 744-1 Door interlock 708-1 Max 45 C 741-1 Connector cover 438-1 Standard Warranty 210-2 7 m 701-1 Flex Pendant 10 m 644-1 French 645-3 Spanish 709-2 Device Net Dual channel 730-1 Device Net Connector on front 716-1 Digital 24VDC I/O 1 727-1 24V 8Amps 731-1 Safety internal connections. 733-1 Panel on cabinet 735-4 Add. Contacts, 2 modes	**Robotic Arm**  **Controller** 

		737-1 Status LEDs at front 907-1 Single drive unit 3 922-1 Prepared for IRBP 601-1 RW 5 Boot package 608 1 World Zones 611-1 Path Recovery 613-1 Collision Detection 633-1 Arc Software 650-7 Standard I/O Welder 652-1 BullsEye 653-2 Binzel - TC97 659-1 Production Monitoring 808-1 Documentation on DVD 1	
2.	1	**IRBP 300kg/AC R Type servo positioning system including:** - ABB's 4th Generation Positioning systems - 300 kg. load capacity per side, including fixture - 16000 mm between head and tail stock -1000 mm Diameter stations - Fast, accurate AC servo-operated indexer -Index time less than 5 seconds Drive unit (located inside robot controller) for all external axes	**R Type Positioner** 
3.	1	**Pallet and fencing for the entire cell to hold:** - Robot - IRBP Positioner - Power supply - Fencing - Robot accessories	**See Above**
4.	1	**Robot riser 24" tall** - All Steel welded construction	**Riser** 
5.	1	**FlexArc Safety** **Safety cell including:** - Safety interface module - Door interlock unit on robot cabinet - Operator station with stack light - Standard safety SICK Light Curtains beams - Safety reset buttons - One man gate for entrance and exit - Modular safety fence around the complete cell - Maintenance gate with interlock **ABB to Provide:** - 2 inputs for HMI dual channel E-Stop to ABB PILZ - 1 E-Stop output, dry contact from ABB PILZ for	**Operator Panel**  **Cell Safety** 

		PLC output status - 1 E-Stop/Light curtain output from ABB PLIZ for Side A Tool. Light drops only when the tool facing operator - 1 E-Stop/Light curtain output from ABB PLIZ for Side B Tool. Light drops only when the tool facing operator	
6.	1	**Fronius Welding package including:** - Fronius TPS 4000 Aluminum package - VR1500 PAP wire feeder - Cooling Unit (FKR4000R-US) - 1 set of drive rolls - DeviceNet cable - Robacta Hose Pack - Robacta 22 degree torch - Ground Cable - Additional Fronius Equipment	

1.2 Compliance to Canadian standards

The IRB manipulators as configured in this proposal with IRC5 controller come with the C-UL mark and do comply with below listed Canadian standards, as outlined by Underwriters Laboratory Inc., file E148974.

- UL 1740, "Standard for Safety for Robots and Robotic Equipment" (Second Edition – November 25. 1998);
- ANSI/RIA R15.06, "Safety Requirements for Industrial Robots and Robotic Systems" (1999);
- NFPA 79, "Electrical Standard for Industrial Machinery" (2002);
- CAN/CSA Z434-03, "Industrial Robots and Robot Systems - General Safety Requirements" (2003); and
- CSA C22.1-02, Canadian Electrical Code, Part I (Nineteenth Edition) Safety Standard for Electrical Installations.

1.3 Documentation

With the purchase of an ABB industrial robotic system, ABB will supply the following to the customer:

One (1) set of documentation that shall include:

1) Standard Robot Manuals
2) Electrical schematics
3) Peripheral equipment manuals.

All documentation shall be generated in accordance with current ABB standards and formats. Preparation of engineering drawings per other formats and delivery of complete detail drawing packages can be quoted upon request by the customer including hardcopies.

2.0 INVESTMENT SUMMARY

2.1 Description	Lot Price
Complete FlexArc R300	**$146,240.00USD**

Estimated shipment for this system is 22-24 weeks.

2.2 Upgrade to Fronius CMT System:

- TPS 4000 CMT
- Cooling Unit
- VR7000 CMT wire feeder
- Robacta 5000 22degree torch
- Additional Fronius equipment

ADD.....$10,680.00USD Each

2.3 BullsEye® II Torch Calibration System:

- Automatically defines robot Tool Center Point (TCP)
- Automatically adjusts incorrect TCP
- Automatically adjusts torch angle

Price per unit.....$3,180.00USD Each

2.4 Fronius Robacta Reamer, including:

- Robacta reamer Alu 3000rpm
- Mounting socket
- Adapter gas nozel milling tool aluminium
- Wire cutter electric
- Controlled automatically by robot controller

Price per unit.....$4,776.00USD Each

3.0 OPTIONAL EQUIPMENT & SERVICES

3.1 Training

Standard training certificates are available to be used at the various ABB training facilities. Training includes one-man one week of robot training at ABB's facility in Brampton

ABB Robotics Training Certificate ..... $2,200.00 ea
Less new robot purchase credit ..... - $700.00 ea
Total ..... $1,500.00 ea

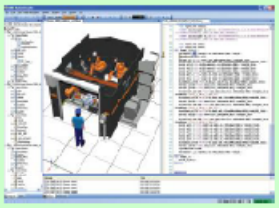
Terms: Training certificates are valid for 12 months from delivery of the robot. Training certificates will be invoiced upon delivery of training course.

3.2 Option for Remote Services

ABB's **Remote Service** concept is aimed at extending the mean time between failure of robots and robotic components. With **Remote Service**, the robot itself automatically alerts the central database. When the customer calls into ABB Technical Support group, the Technical Support person can immediately access a detailed data and error log and quickly identify the exact fault. In 50% of cases, the robot can be brought back on line without any further intervention.

Remote Service Subscription price $2,200.00USD/year,ea
Less new robot purchase credit ..... - $300.00 ea
Total ..... $1,900.00USD/year ea

3.3 Option for RobotStudio™ 5.0



RobotStudio 5 is the leading product for offline programming on the market. With its new programming methods, ABB is setting the standard for robot programming worldwide. Offline programming reduces the risk by visualizing and confirming solutions and layouts before the actual robot is installed, and generates higher part quality through the creation of more accurate paths.

Total ..... $1,500.00/year ea

3.4 Option for ArcWelding Power Pac for RobotStudio™ 5.0

ArcWelding PowerPac is a dedicated programming tool for generating arc weld programs and is based on RobotStudio. ArcWelding PowerPac and RobotStudio utilize the CAD geometry as the basis for all robotics programming.
ArcWelding PowerPac saves time and money. With ArcWelding PowerPac you can program your robots offline without taking them out of production.

Total ..... $1,500.00/year ea

3.5 Onsite Installation Assistance/Traning

ABB's proposal includes 40 hours of ABB on-site training/installation and support at the University of Manitoba - Winnipeg, Manitoba.
On-site support includes one (1) ABB Field Service Tech or Specialist at the above facility to provide technical support, electrical installation assistance, equipment start-up, debug activities, and general set up services. Any training will be informal and does not include any specific training materials.
The actual time may vary based upon on-site conditions, plant-operating procedures, availability of the customer-supplied equipment, utilities, peripheral equipment, and the customer supplied technicians. Any additional time required to perform the above services would be provided on a time and material basis.
Installation has been quoted to take place during regular business hours.
(Mon- Fri – between 7am and 5pm)

Price $9,320.00USD

- Travel time and expenses Included

4.0 ASSUMPTIONS & CUSTOMER RESPONSIBILITIES

In order to prepare this proposal, we have made the following assumptions:
By accepting this proposal above the University of Manitoba acknowledges that this proposal has been read in its entirety and the concerned parties are fully aware of the scope of supply, assumptions and Customer Responsibilities. Any additional charges resulting from misunderstanding or lack of knowledge on the customer's part are likely to cause additional charges due to delays, change orders, or additional modifications.

a.) ABB is not responsible for any process development as it pertains to this proposal.

b.) University of Manitoba to confirm robot specifications prior to placing order.

5.0 GENERAL TERMS & CONDITIONS

Our standard "Terms and Conditions of Sale for ABB Products" form part of our proposal, unless otherwise stated below:

1.0 Shipping is Ex works, Brampton.

2.0 All applicable taxes including GST are extra and in addition to our price.

3.0 Terms of payment are 25% at time of order (net 7 days), 25% upon dispatch of robots from factory in Sweden (net 14 days), 50% upon delivery (net 30 days).

4.0 Price is valid for 15 days.

5.0 Delivery time is 22-24 weeks from Purchase Order acknowledgment.

6.0 Costs incurred due to delays in agreed shipment dates or scheduled on-site work may be invoiced if at no fault of ABB.

7.0 All pricing is in USD currency unless otherwise specified.

8.0 This proposal reflects our understanding of the full extent of ABB's scope of supply. It is the responsibility of the customer to clarify any items or compliance to specifications outside the scope of this proposal.

9.0 Parts and labor warranty is 12 months from shipment. Expenses are extra. This warranty shall not apply to any equipment or parts which (i) have been improperly installed, repaired, or altered, (ii) have been subject to misuse, negligence, or accident, or (iii) have been used in a manner contrary to ABB operating and maintenance procedures.

10.0 Duties and brokerage are included for Canadian bound machines. Robots destined to countries other than Canada do not include duties and brokerage to the destination country of the end user.

6.0 ORDERING INFORMATION

Send Hard Copy P.O. to:
ABB Inc.
201 Westcreek Blvd
Brampton, Ontario, L6T 5S6

Reference Quote Number: Q11-0506
Attn: George Paton

For faster service, fax a copy of your purchase order to (905) 460-3019, ATTN: Sherry Humber-Carter

7.0 ENCLOSURES

- ABB Inc. Terms & Conditions