FLEX·CABLE
Engineered Solutions

Reducing and Eliminating Down-Time in Resistance Welding Systems

Preventative Maintenance Handbook

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Engineered Solutions

In today's world of rapid growth and high technology, where a product can be here today and gone tomorrow; service, quality and technology are the key assets which separate the few from the many. For more than 55 years, Flex-Cable has developed these assets in order to be recognized as a leader in Resistance Welding Cable technology.

The Flex-Cable team has strived to set high standards and then go beyond them. The results? Operating at a world-class level of engineering and manufacturing capacity that allows for:

- Increased quality
- Increased flexibility
- Superior customer service
- Leading innovation
- Decreased cost
- Minimize lead time

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Introduction

Continuous Improvement at Flex-Cable keeps us at the Front in welding technology. During this constant improvement process we have learned many ways to make cables last longer and reduce down time related to cable failure. This knowledge can be a vital tool in reducing total cost of operation, increasing operational efficiency, and making everyone's job much easier.

Most everyone knows that proper cable selection will increase cable life. It is also becoming a well known fact that proper dress out of a robot will increase cable life. Both of these save money and reducing down time. However, it is not well known that through a properly implemented preventative maintenance program, down time related to resistance welding cables can be virtually eliminated.

This pamphlet contains information that can be used on any level from new builds or retro fits to everyday operation. Sections 2 & 3 cover cable selection, Section 4 covers robot dress out and Sections 5 & 6 cover Preventative Maintenance. Section 7 is a complete example of a Preventive Maintenance Program in place. All of the forms shown are available from Flex-Cable along with simple templates for use on computers.

The information used to create this document was derived from many years of testing and continuous research performed by our engineering department as well as independent testing laboratories such as Candid Logic.

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Sizing a Cable

Sizing a Secondary Resistance Welding Cable is important due to the two internal enemies, heat and mechanical stress. To combat these enemies remember that smaller is better. This means that one should follow two simple rules of thumb.

Use the Shortest Cable that will properly do the job Mechanically.
Use the Smallest Size (MCM) cable that will properly do the job Electrically.

Using the proper length cable is important so that heat and the mechanical stress will be minimized. The longer the cable the more resistance, this means that the transformer voltage must increase to get the desired current and that more heat will be generated, and will need to be removed from the cable. Secondly, if the cable is too short the bends on the cable will be tighter and cable life will be reduced due to mechanical stress. **Use the Shortest Cable that will properly do the job Mechanically.**

Likewise the correct MCM size will also minimize heat and mechanical stress. If a cable is sized too small the resistance will be great and more heat will be produced causing the cable to overheat. If too large on an MCM size is used, the mechanical forces on the cable are increased and this will contribute towards the mechanical destruction of the cable. **Use the Smallest Size (MCM) cable that will properly do the job Electrically.**

Determining cable length is relatively simple, and when dressing a robot the correct length is first estimated and then sometimes needs to be adjusted as the dress out is finalized. It sometimes is useful to use a length of hose, (10'-12') to simulate the actual cable and it's routing.

Cable sizing is more complicated. The length must first be determined, then the water flow, thirdly the RMS Current. The RMS Current is derived from the maximum weld current, the weld time, and the welds per minute (Duty Cycle.) An easy to use tool for doing this computation is the Flex-Cable slide chart (Due to the way that this chart was derived we recommend using it only on Flex-Cable products).

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Cable Types

There are many different types of cables on the market today, with the differences being both internal (the makeup of the cable) and external (the type of covering or hose.) This section will first describe some of the differences and give reasons for choosing a certain type of construction. Following that are some typical applications and the corresponding type of cable recommended.

First we will cover the different types of internal construction of kickless cables. Some cables use an 'opposed polarity' construction while others use a 'alternate polarity' construction. In the 'opposed polarity' construction the ropes of wire for each polarity are grouped together, which raises the impedance by creating a large magnetic field and lowers the power available for welding (in some cases the tap switch for the transformer may need to be turned up.) In a 'alternate polarity' format the ropes of wire for each polarity are arranged in an alternate configuration. This helps to cancel out some of the magnetic field, which lowers the overall impedance (more power available for welding.) Flex-Cable uses the 'alternate polarity' construction in our kickless cables.

Another way that kickless cables can differ is in the number of wire ropes used in the construction of the cable. Kickless cables can be constructed using 6 ropes of wire or just 4 ropes. The 6 rope construction has several advantages. Since each polarity has 3 smaller ropes of wire instead of 2 larger ropes, the cable lasts longer when being bent or twisted. Another important characteristic is that when a cable starts to fail, the process is slower and more easily measured. Flex-Cable has always used the 6 rope construction since we developed it many years ago.

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Cable Types (Cont.)

The method in which the cables are separated and insulated within a kickless cable can also differ. The main two ways are by using a separator (a core with 'fins' evenly spaced around it to hold the ropes of wire) and individually encasing each wire rope within the cable. The material that is used to "Individually Wrap" each rope of wire both insulates the ropes from each other and helps to keep copper strands from entering the water system. At Flex-Cable we offer both types of construction, referring to the separator style of construction as 'Standard' Construction and the individually wrapped style of construction as 'Flex-Cel' Construction. The 'Flex-Cel' style of construction has more advantages than mentioned above. It will bend and twist easier than standard construction which is important for manual guns, and due to the more open structure on the inside of a cable it will last longer in tight bend and twist applications.

Just as there are many different types of interior constructions, the cable coverings or hoses have many varieties also. The most common hose material in use today is a reinforced blend of natural rubber and SBR. The reason that rubber, (natural or SBR) is used is that it is a thermal set material, which means that if the temperature increases, the hose will not melt. All of Flex-Cable's hoses utilize this type of construction with variations depending on specific cable application. The exterior of the hose is also equally important and Flex-Cable offers a wide variety of hoses to meet many different uses.

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Applications

General Robotics Applications

After many years of continuous testing and improvement Flex-Cable developed Color-Flex. It is the most common type of cable available for typical robotic applications. The Color- Flex cable has been tested by in independent laboratory and outperformed the competition as much as two to one for cable life. This combined with the field proven track record is why the Color- Flex cable is the recommended specification by many in the welding industry. The outside hose has a durable rubber blend outer covering which gives good support for the cable while allowing the cable to bend and twist. The rubber blend is the same as that used in sandblasting hose and thus is very good at resisting abrasion. The interior of the Color-Flex Cable is with 'Standard' style of construction.

Tight Bend/Twist Robotic Applications

The America's Power Cable type of construction is the solution if the application performs tight bends or many bends and twists. The Interior of the America's Power Cable is made with the 'Flex-Cel' style of construction and uses the same style of hose as the Color-Flex, giving good support and resisting abrasion. This construction has been both laboratory and field tested with excellent results proving that this is a cable that has a extended life over the Color-Flex cable.

High Abrasion Applications

The Euro-Flex is by far the best cable for high abrasion applications. Euro-Flex Cables have all of the benefits of the America's Power Cable with the addition of a Polyurethane outer covering which provides superior resistance to abrasion. Euro-Flex cables combine all of the advantages of a reinforced rubber hose with the abrasion resistance of urethane and the durable interior 'Flex-Cel' construction creating the highest performing cable ever. Testing done by an independent laboratory has shown that the Euro-Flex cable has both longer life in severe bending and better resistance to abrasion than any of our competitors.

Manual Gun Applications

A cable that is easy to bend and twist is needed for manual gun applications. We developed Complex hoses specifically for this application. A Complex cable has excellent flexibility thus reducing the ergonomic stress on the gun operator while maintaining the safety of a reinforced rubber tube on the inside. This combined with 'Flex-Cel' construction makes the Complex cable the choice of operators. For these reasons Complex has become the recommended specification within the welding industry for manual guns. Because of the use of softer rubber to make Complex more ergonomic, use of this type of cable cover should be restricted to manual operations only.

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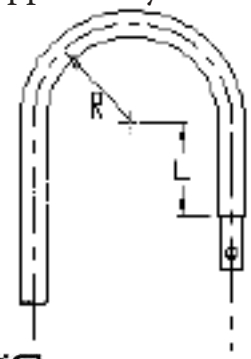
Optimizing Robot Dress Out

'Proper Robot Dress Out' is a phrase that can take on many meanings and have many different levels. There is no absolute right or wrong way. There is no perfect dress out. There are only those that work well and those that do not. The goal in any robot dress out is to have the cables, wires, and hoses all last as long as possible. For the cables, the way to achieve this is to minimize twisting, bending and abrasion. That would be easy if the robot did not move. However, since this is not the case, here are some important notes that will help in robot dress-out and increase cable life.

Use high quality dress out equipment and accessories. Use equipment that will not bend, break, burn or melt. Robots accelerate and stop at remarkable speeds which create extremely large forces acting on the equipment. The use of dress out equipment (based on a modular system) is extremely helpful when trying out a new dress out idea. Utilizing a system (such as Robo Com V) that will allow the cable or hoses to be mounted almost anywhere has definite advantages.

Run the robot through it's cycle(s) many times to ensure that the dress out keeps the cable and hoses from contacting other surfaces, without being kinked or bent too tightly. The minimum bend radius for Flex-Cable Kickless cables as well as the start of radius from the end of the hose is given in the chart below. Through testing we have found that for applications where tight bending can't be avoided, the use of 'Flex-Cel' cables will greatly increase the life of the cable.

If contact between the cables/hoses and other items cannot be eliminated by dress out, then there are other ways of reducing the effects of abrasion. For the cable, the choice of Euro-Flex hose will minimize the effects of abrasion to the lowest point possible. The hoses can be dressed into a Robo-Harness (a polyurethane housing keeping the hoses together while providing abrasion protection.) Another option for protection is the use of EXO (a nylon material available in different coil sizes) that can be applied anywhere needed.



Cable Size	300 / 400	450 / 500	650	800
Min. Bend Radius (R)	5	5 1/2	6 1/2	8 1/2
Start of Radius From End of the Hose (L)	5 1/2	6 1/2	7 1/2	9 1/2

Length in Inches

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Preventative Maintenance I (Physical)

The first step in good cable maintenance coordinates well with proper dress out. Cable and hose life can be extended with the use of periodic inspections. The time interval for the checks are subject to many factors, but motion of the robot and proper dress out are two of the main items. The inspection interval should be determined by each plant and perhaps each robot. A general guideline for this is once a week.

Things that need to be checked are:

- ► No abrasion, cracks or delamination of the rubber on the cable or hoses.
- ► All bolts are tightened properly.
- ► No water leaks.
- ► While running the robot through it's cycles check to make sure that there are no kinks in the hoses or wires and that the bend radius on the cable is not too small.
- ► Any controlling wires are not being pinched or kinked.
- ► A minimal amount of breaking strands on air cooled cables or no signs of over heating.
- ► Water Flow for the Cables

Any problems found should be fixed or monitored on a more frequent basis.

A simple checklist is included in the appendix that could be used for each robot or cell of robots (Document CL-1.)

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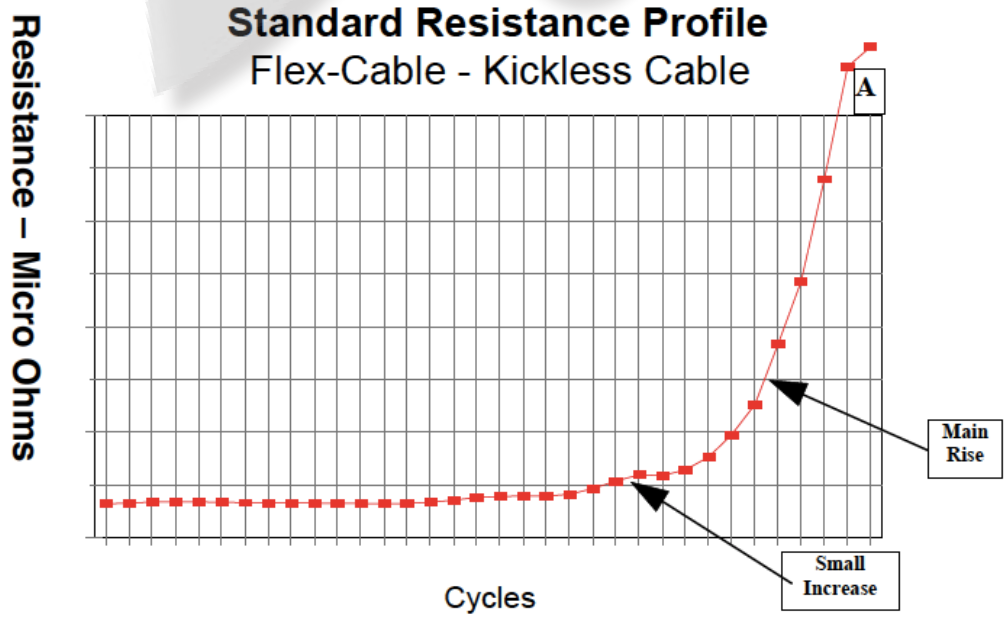
Preventative Maintenance I (Electrical)

The second step, and probably the largest factor in preventing down time, is to change cables before they fail. To make this a cost effective method the cable has to function as long as possible and then be changed before a failure occurs.

We have developed a process in which this can be done. Through much testing (laboratory and field) and accumulation of data we have found that the resistance of a Flex-Cable kickless cable will have the profile as shown in the following graph (figure 6-1). Most applications will deliver a 'no weld' or the cable will fail at point A, so the cable should be changed before that point. The best time to change a cable is during the 'Main Rise', however, in some cases it may be necessary to change the cable during the 'Small Increase' if the conditions are extremely harsh.

The graph below shows a typical profile that was logged with severe robot test cycles, but would look similar when logged over a nominal time. As mentioned above the time interval for the checks are subject to many factors and should be determined by each plant and perhaps each robot. A general guideline for this inspection interval is once a week. We have set up a simple method in which to obtain and record the resistance each week.

Note: This profile is typical for Flex-Cable Kickless cable only. The profile of other cables on the market that do not use a 6 rope construction have a much more sudden rise to point A giving less time for detection.



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Preventative Maintenance I (Electrical)

The cut off limits for the cables were determined using test data obtained from our testing facility and actual data from plants. These are just a guideline and may need to be modified to suit the needs of your plant. See the charts in appendix A (Document TC1 - TC4) for more information on the cut off limit for different sizes and length cables.

To utilize the Tracking Charts simply start with a blank copy (corresponding to the MCM size that you are using.) Draw a line in at the cut off point for the cable length. Start when installing the cable and then each week take a resistance measurement of the Kickless cable and put a dot on the chart corresponding to the reading. Connect this dot to the previous marks and the profile will soon be apparent. When the cable has a resistance reading above the cut off value, it should be changed so as to prevent down time from failure.

If the recommended cut off value is too low or too high, (cable is removed too soon or it fails) a new cut off value can be determined by using the same chart. Instead of drawing the line on the Tracking Chart when starting a new chart just log the resistance with the date as before but leave the cable on until it fails. This will allow you to see what the profile looks like so that a new cut off value can be determined.

The new EZ-CHK Cable combined with the EZ-CHK package, for the Flex-Cable Lunch Box Micro Ohm Meter, makes taking preventive maintenance resistance readings quick and easy. Also, for further help, Flex-Cable's Sales and Customer Service teams are available to answer any questions.

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Complete Flex-Care Example Index

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Physical & Electrical Check List And Data Sheet

Flex-Care PM Program **Robot:** 32R1-1

CHECK LIST	Initials
PHYSICAL	
Cables	
Abrasion/Cracks on Hose	
All Bolts Tightened	
Cables & Hoses	
No Water Leaks	
No Kinks in hose/cable	
Air Cooled Cable	
Over Heating	
Many Strands Broken	
General	
Control/Prox. Wires OK	
Water Flow	
ELECTRICAL	
Kickless Cable 1 +	
Kickless Cable 1 -	
Kickless Cable 2 +	
Kickless Cable 2 -	
Water/Air Cooled Cable 1	
Water/Air Cooled Cable 2	
Total System tip to tip	
DATE	

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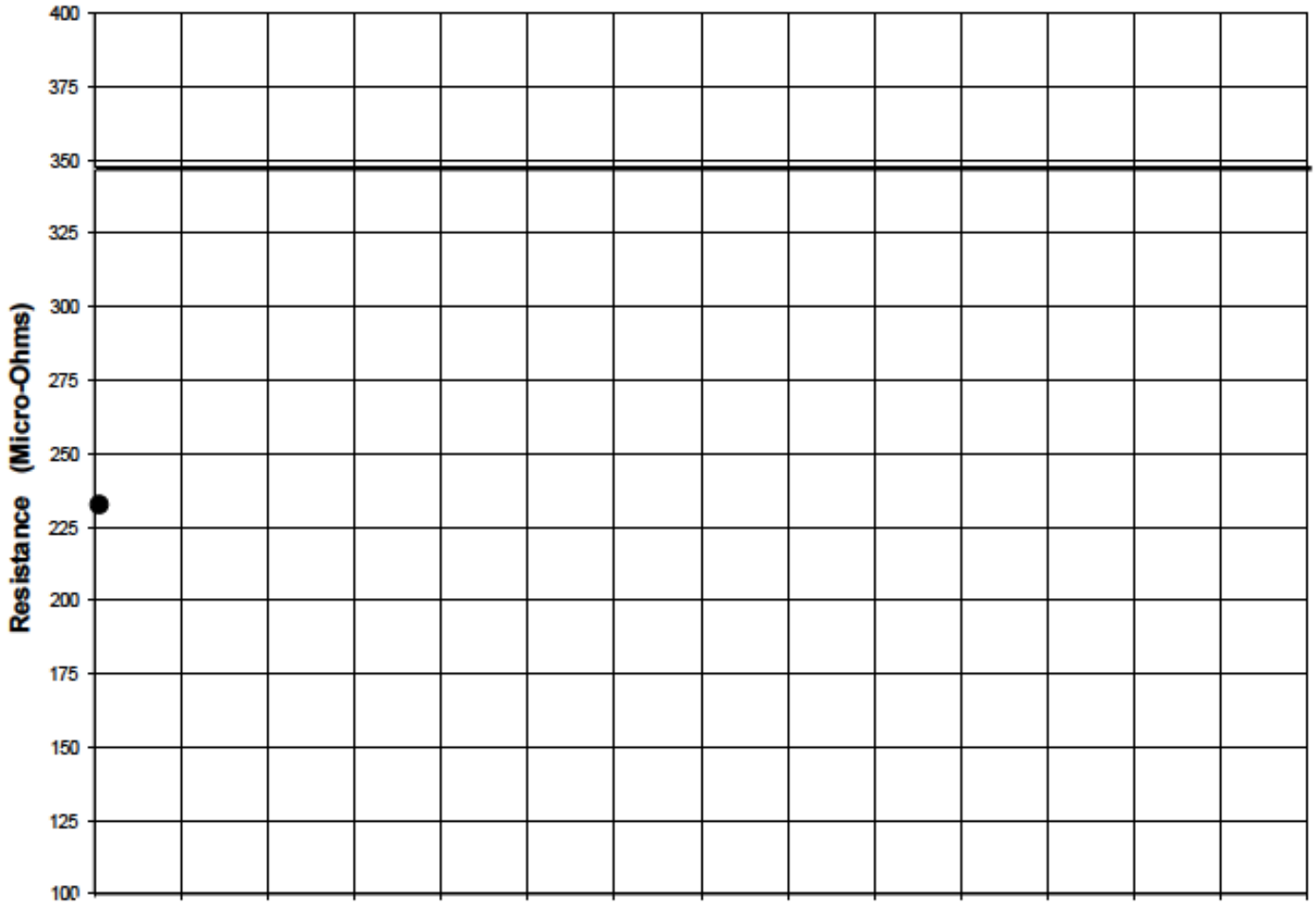
400 MCM Kickless Cable Resistance Chart

Flex-Care PM Program **Robot:** 32R1-1



Date

Resistance Cut-Off Values

LENGTH	CUT-OFF
4	155
5	192
6	231
7	269
8	308
9	348
10	386

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Over Heating	
Many Strands Broken	
General	
Control/Prox. Wires OK	
Water Flow	
ELECTRICAL	
Kickless Cable 1 +	
Kickless Cable 1 -	
Kickless Cable 2 +	
Kickless Cable 2 -	
Water/Air Cooled Cable 1	
Water/Air Cooled Cable 2	
Total System tip to tip	
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400 MCM Kickless Cable Resistance Chart

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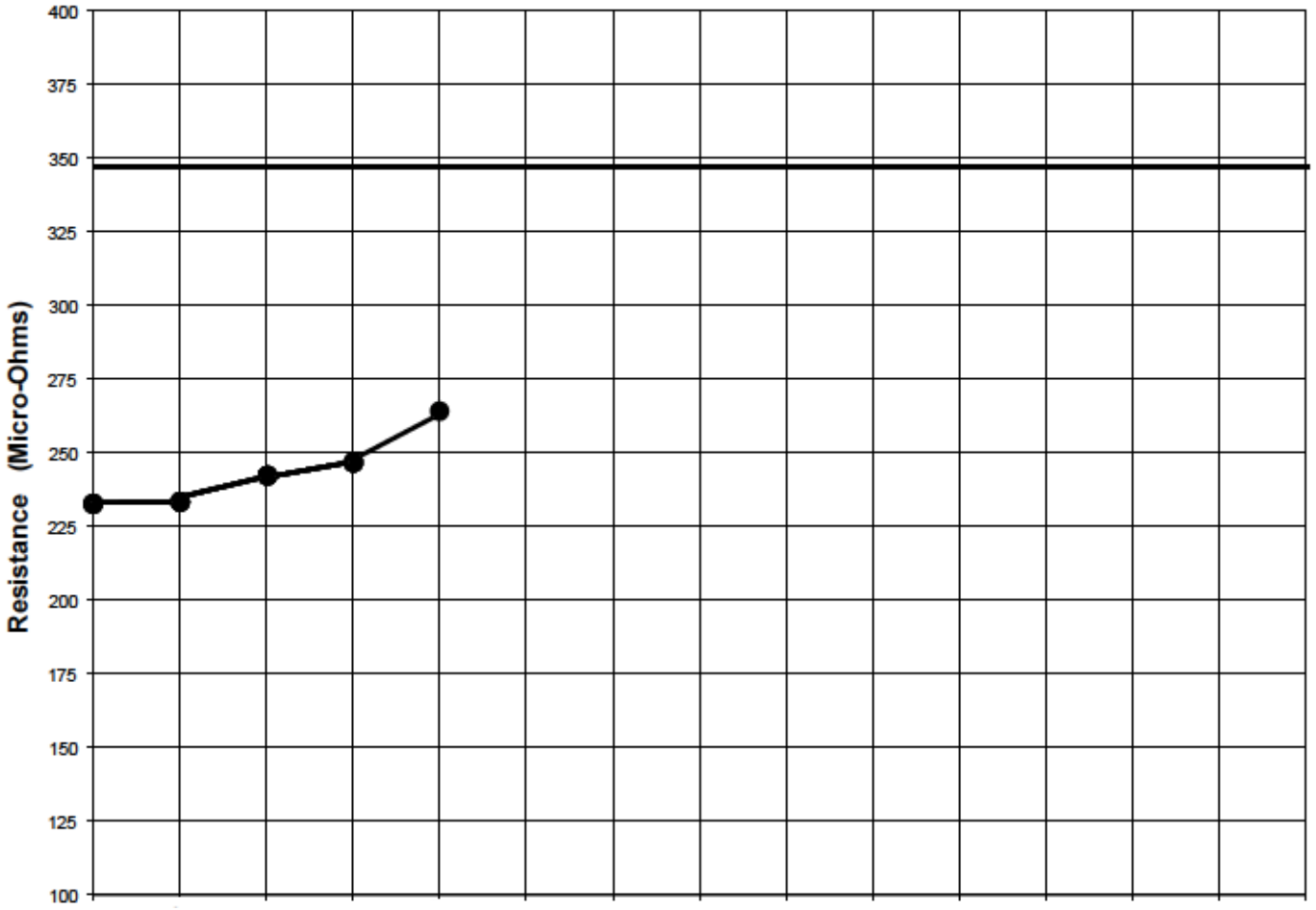

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Water/Air Cooled Cable 2	
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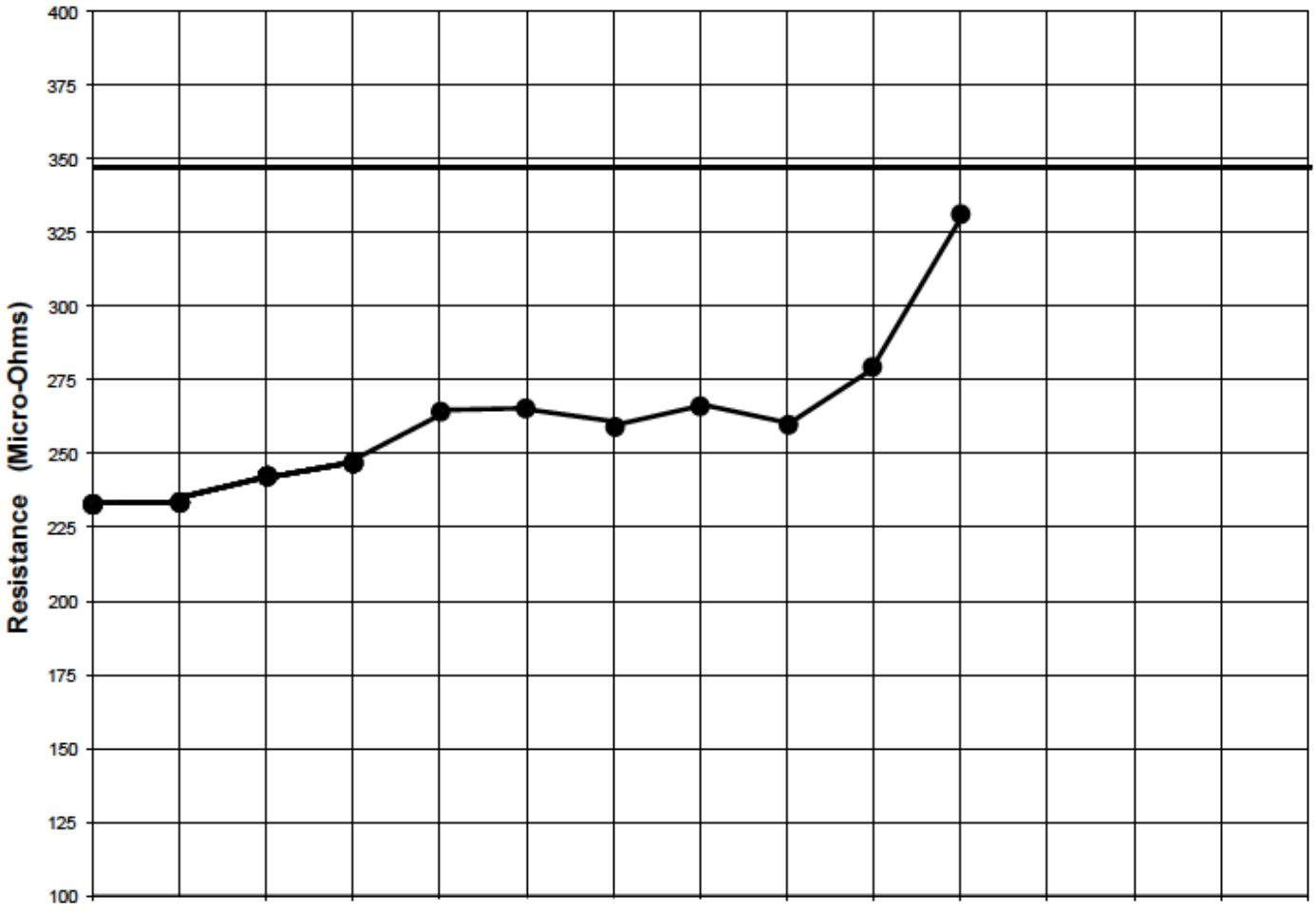

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Water/Air Cooled Cable 2	
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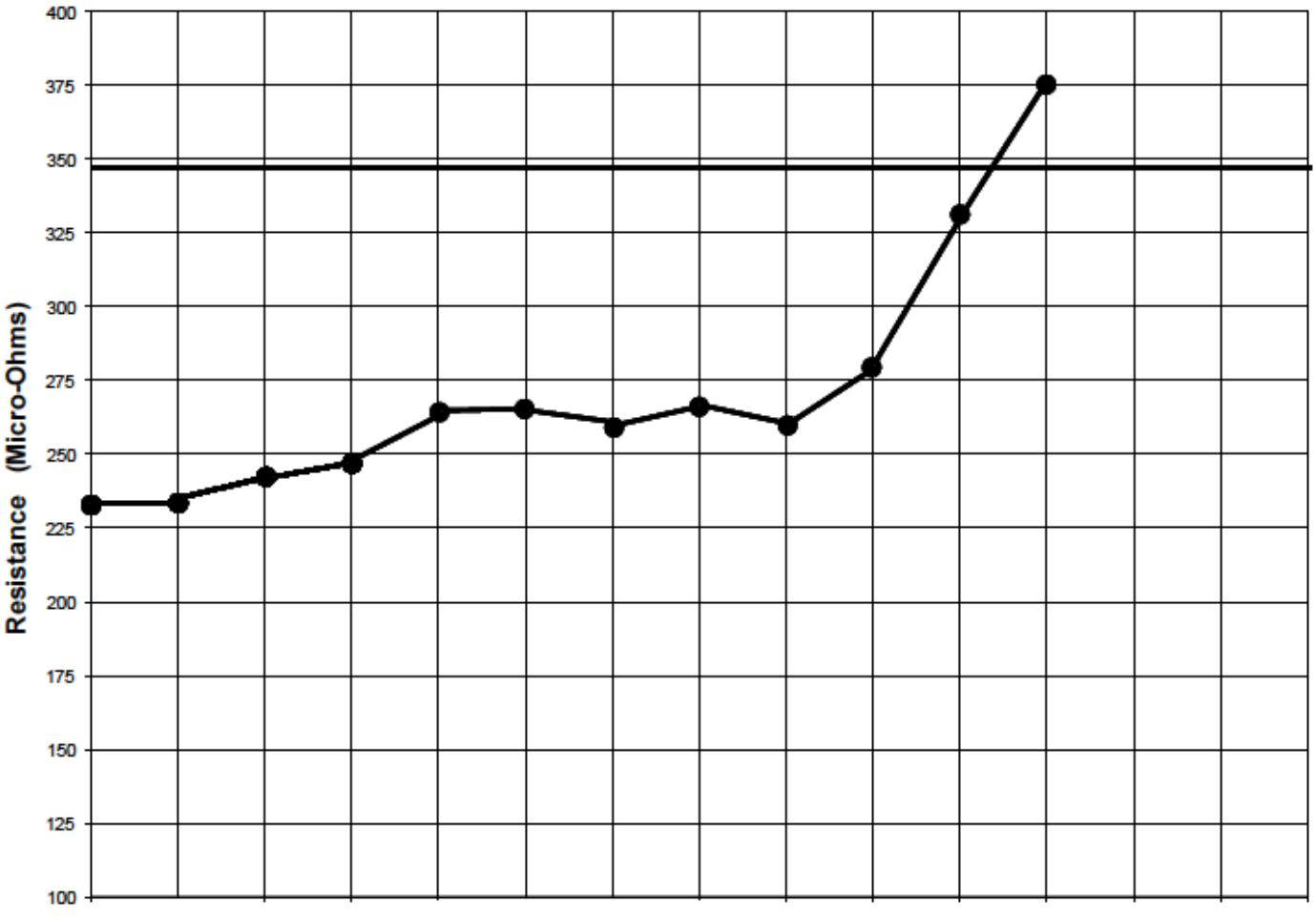

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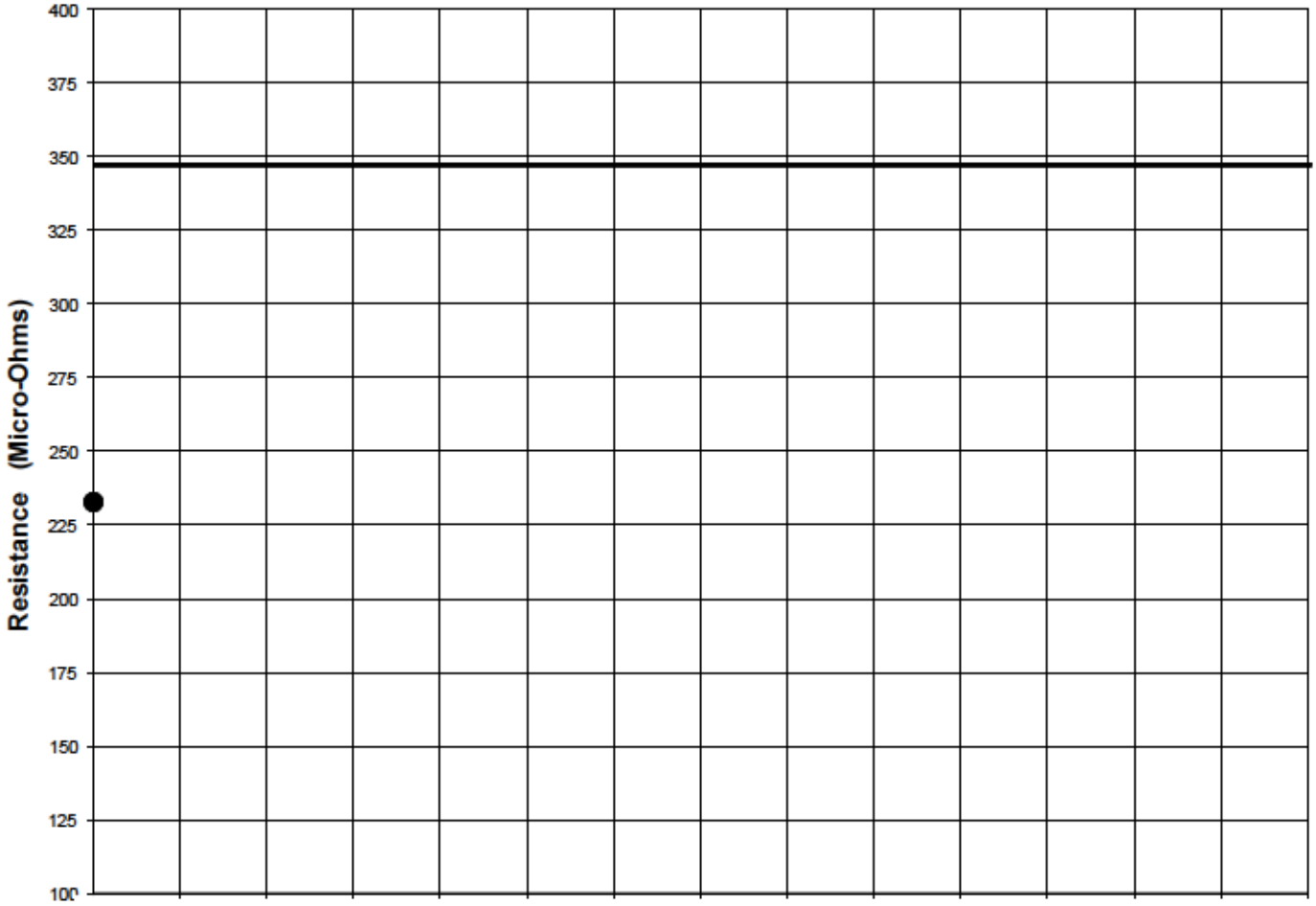

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Kickless Cable 2 +	
Kickless Cable 2 -	
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Water/Air Cooled Cable 2	
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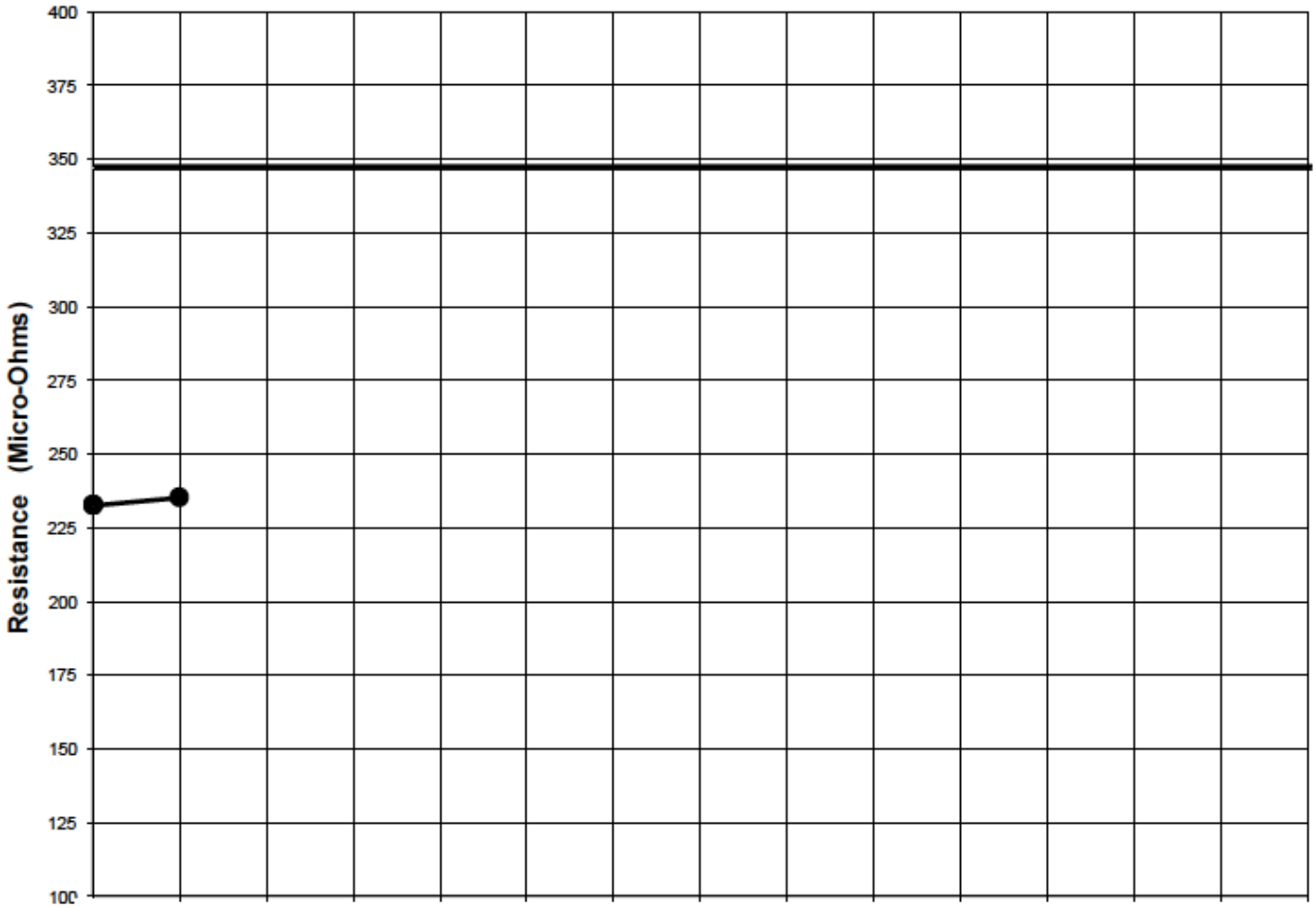
400 MCM Kickless Cable Resistance Chart

Flex-Care PM Program **Robot:** 32R1-1



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Appendix A - Forms

Forms Index

Check List 1	-Physical & Electrical Check List Data Sheet
Tracking Chart 300 Chart	-300 MCM Kickless Cable Resistance Tracking
Tracking Chart 400 Chart	-400 MCM Kickless Cable Resistance Tracking
Tracking Chart 500 Chart	-500 MCM Kickless Cable Resistance Tracking
Tracking Chart 650 Chart	-650 MCM Kickless Cable Resistance Tracking

Physical & Electrical Check List And Data Sheet

Flex-Care PM Program **Robot: _____**

CHECK LIST	Initials
PHYSICAL	
Cables	
Abrasion/Cracks on Hose	
All Bolts Tightened	
Cables & Hoses	
No Water Leaks	
No Kinks in hose/cable	
Air Cooled Cable	
Over Heating	
Many Strands Broken	
General	
Control/Prox. Wires OK	
Water Flow	
ELECTRICAL	
Kickless Cable 1 +	
Kickless Cable 1 -	
Kickless Cable 2 +	
Kickless Cable 2 -	
Water/Air Cooled Cable 1	
Water/Air Cooled Cable 2	
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DATE	

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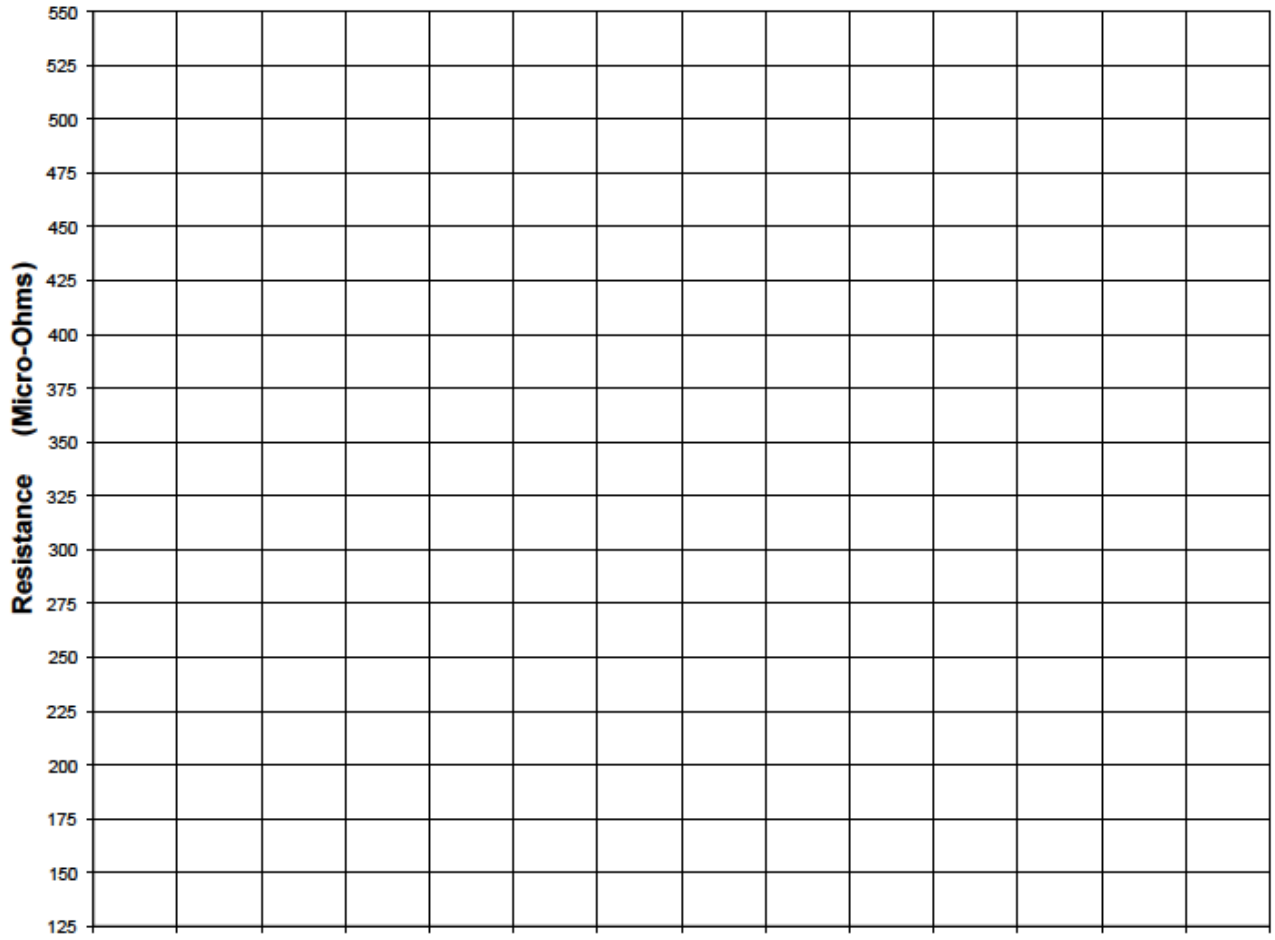
300 MCM Kickless Cable Resistance Chart

Flex-Care PM Program **Robot: _____**



Date

Resistance Cut-Off Values

LENGTH	CUT-OFF
4	207
5	258
6	312
7	360
8	414
9	467
10	521

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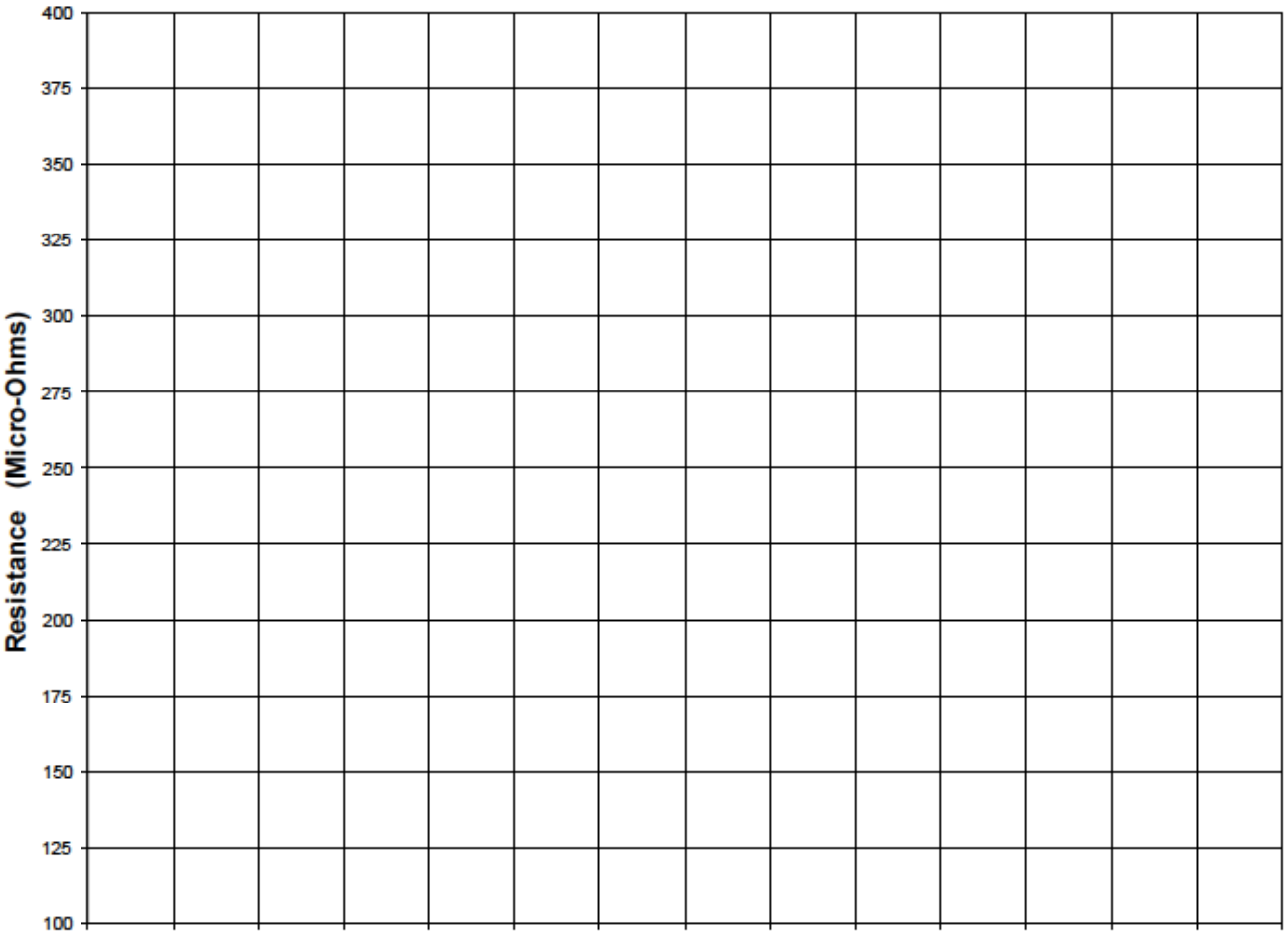
400 MCM Kickless Cable Resistance Chart

Flex-Care PM Program **Robot: _____**



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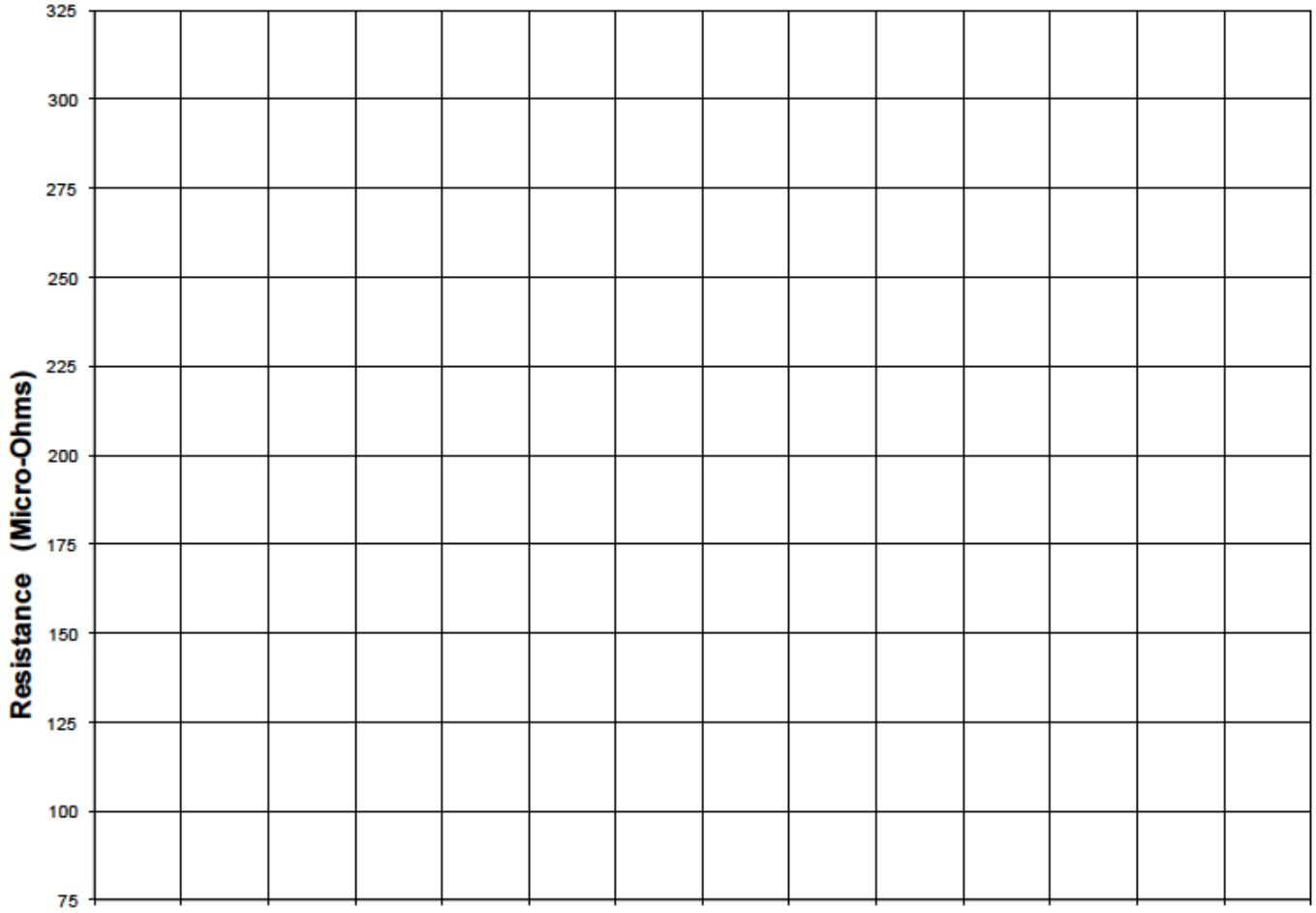
500 MCM Kickless Cable Resistance Chart

Flex-Care PM Program **Robot: _____**



Date

Resistance Cut-Off Values

LENGTH	CUT-OFF
4	126
5	158
6	189
7	221
8	252
9	284
10	315

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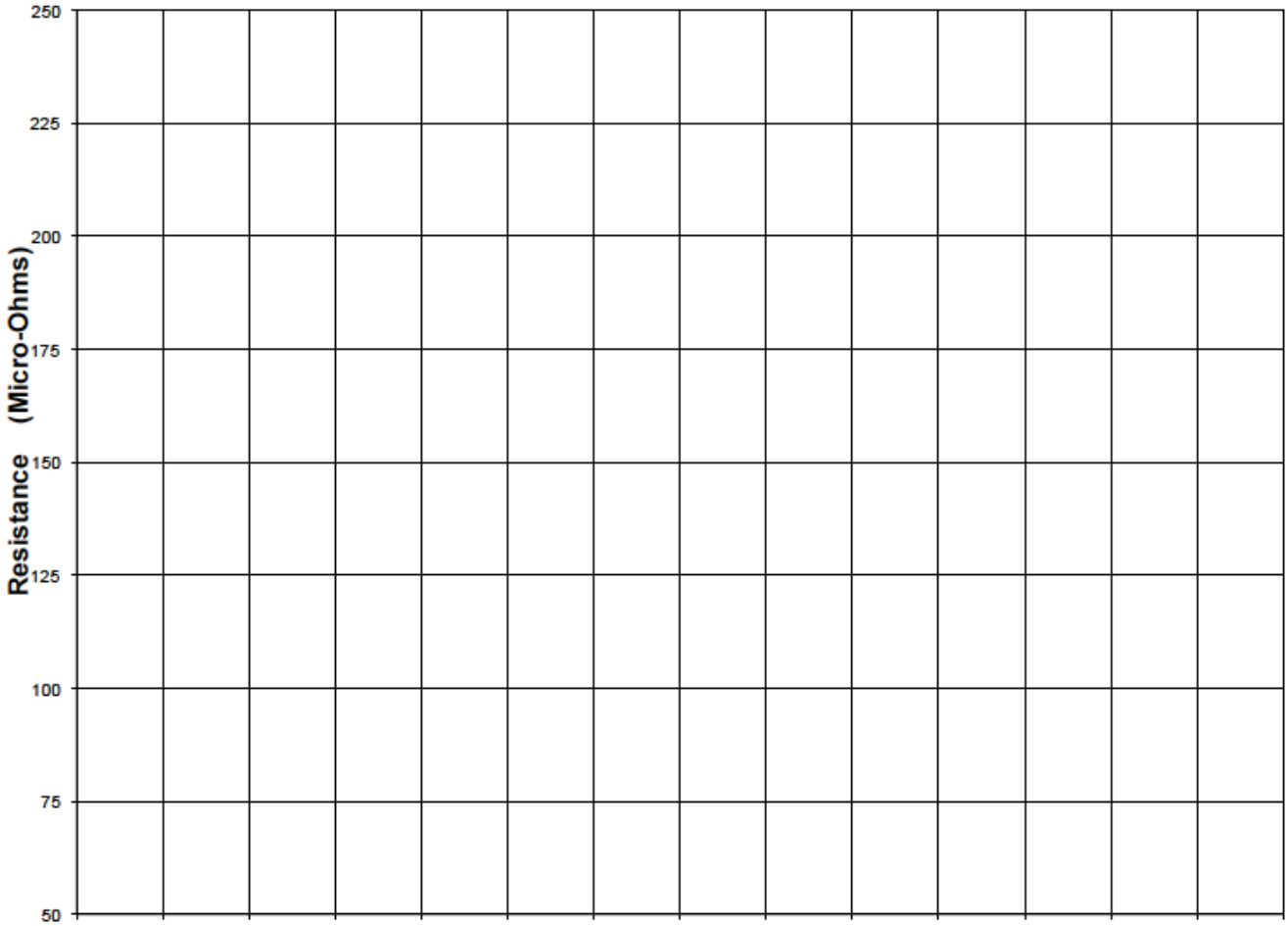
650 MCM Kickless Cable Resistance Chart

Flex-Care PM Program **Robot: _____**



Date

Resistance Cut-Off Values

LENGTH	CUT-OFF
4	95
5	119
6	143
7	165
8	191
9	213
10	237

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Appendix A - Forms

Micro & Milli Ohmmeters "Lunch Box"

Economical troubleshooting tools to help increase up-time

Micro-Ohmmeter: troubleshoots secondary welding circuits.
Measuring Range: 3-1999 micro ohms

Milli-Ohmmeter: troubleshoots primary circuits.
Measuring Range: 0.3-199 milli ohms

Micro-Ohmmeter: Part Number= MOCT7550
Milli-Ohmmeter: Part Number= MOCT7600

FLEX·CABLE

Flex-Cable's Other Product Lines

Flex-Cable doesn't just make products, we solve problems in the manufacturing sector for all customers.

Custom Cables

- Rectangular Connectors
- Military Connectors
- Circular Connectors
- Custom Assemblies
- Private Label Over-Molding
- I/O Fan Out Cables

Motion Control Cables

- Servo Motor Cables
- Servo Motor Extension Cables
- Servo Motor Box Mount Cables
- Servo Motor Purge Cables
- Resistive Brake Module Cables
- Stand-Alone Encoder Cables
- Break-Out Boards
- Transition Cables
- Feedback Cables

Robot Dress

- Components (Clamps, Brackets, etc)
- Retract Dress Systems
- Static Dress Systems
- Universal Dress Systems
- MIG Assemblies
- Cables & Hose Protection
- Custom Umbilicals
- Robot Bypass Box

Bus Bars

- Solid Bus Bar w/ PEM Studs
- Round Cable to Flexible Bus Bar
- Round to Flat to Round Wire
- Flexible Bus Bar
- Round Cable
- Solid to Flexible Bus Bar
- Shielded Bus Bar
- Aluminum Bus Bar
- Jumpers

Furnace Products

- Carbon Arc Cables
- Induction Furnace Cables
- Induction Heating Cables
- Low Impedance Cables
- Air Cooled Cables
- Copper Repair & Rebuild Services

Injection Molding

- Custom Molded Plastic Parts
- Plating Options Available
- Finishing Options Available
- Short Run & Prototype Molds
- Multi-Component Capability

Copper Stamping and Fabrication

- Hybrid/Electric Vehicle Specialty
- Simple Blankings
- Complex Stamping Dies
- High Production Capability
- Non-Ferrous Specialty
- Plasma Cutting

Metal Fabrication

- Sheet Metal Fabrication
- Welding Services
- Milling & Drilling
- Turning
- Custom Machining
- Plating Options Available

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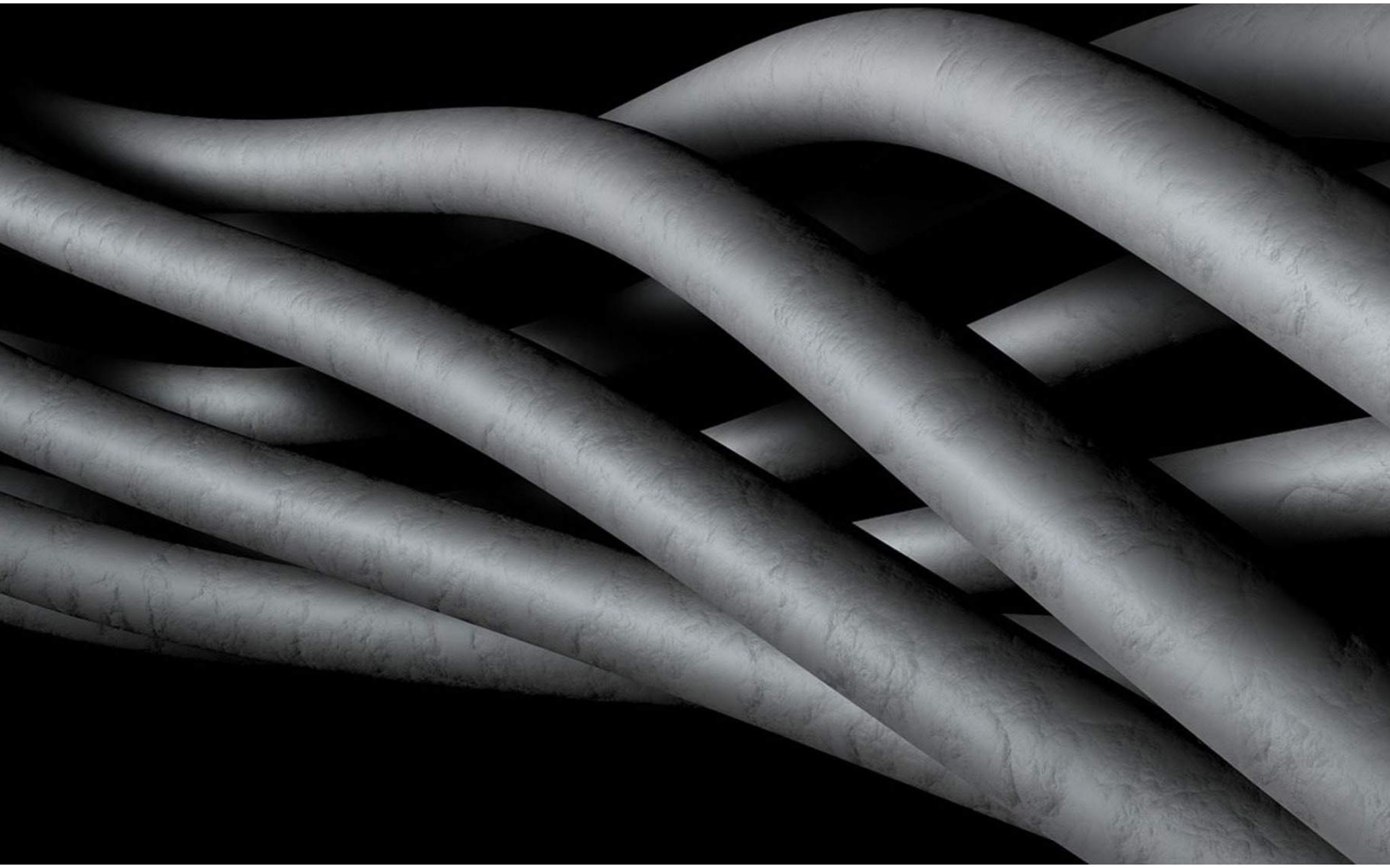
Engineered Solutions



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