Contact
Contamination and Arc Interactions

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Particle Contamination

The effect on contact area for increasing each parameter

Parameter	Effect	Comment
Particle size	Negative	Area of influence may be much larger than actual particle size
No. of particles	Negative	The product of this and the area of influence determines probability of make
Surface roughness	Positive	Decreases area of influence
Load force	Positive	Increases contact area
Hardness	Negative	Lowers contact area per force

Reference: Williamson & Greenwood

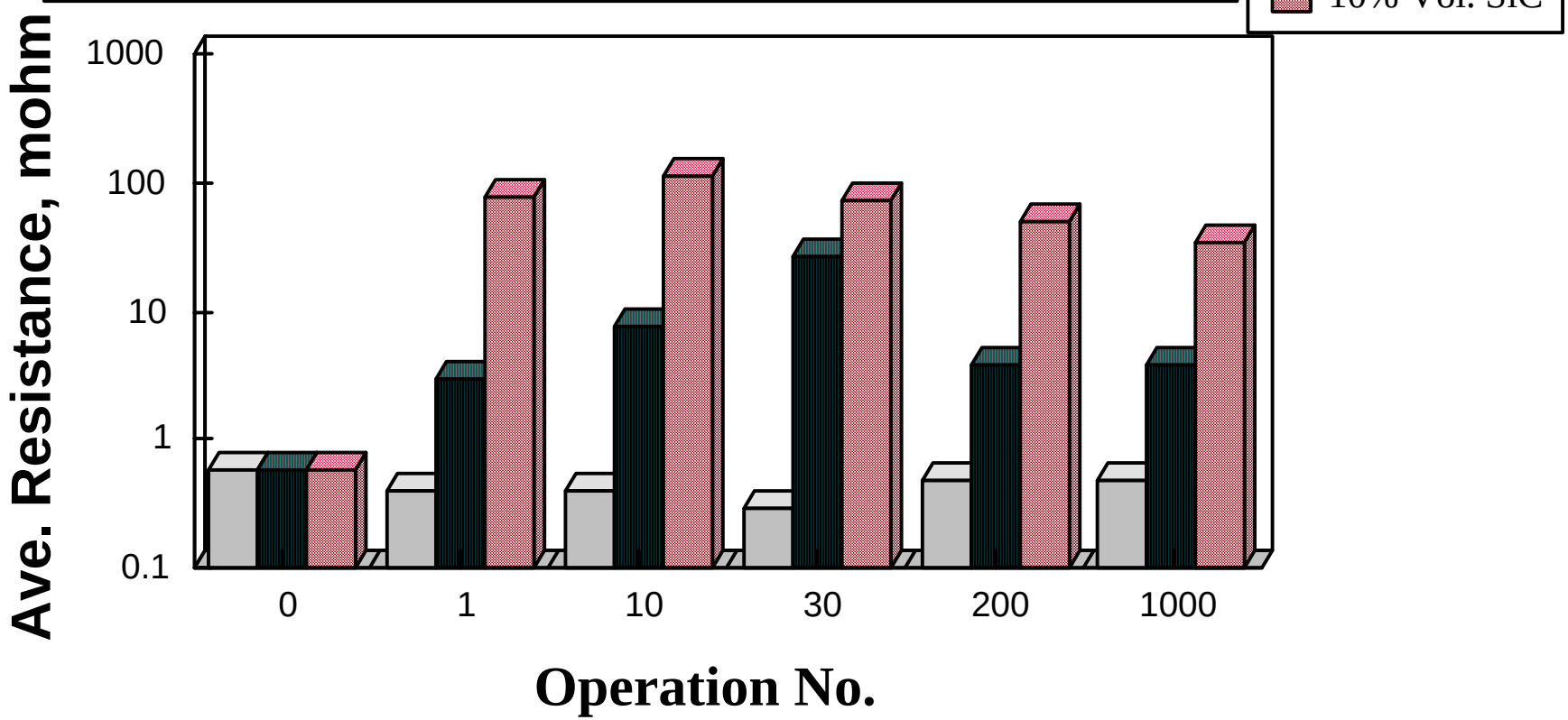
Fast Forward 50 Years to Present

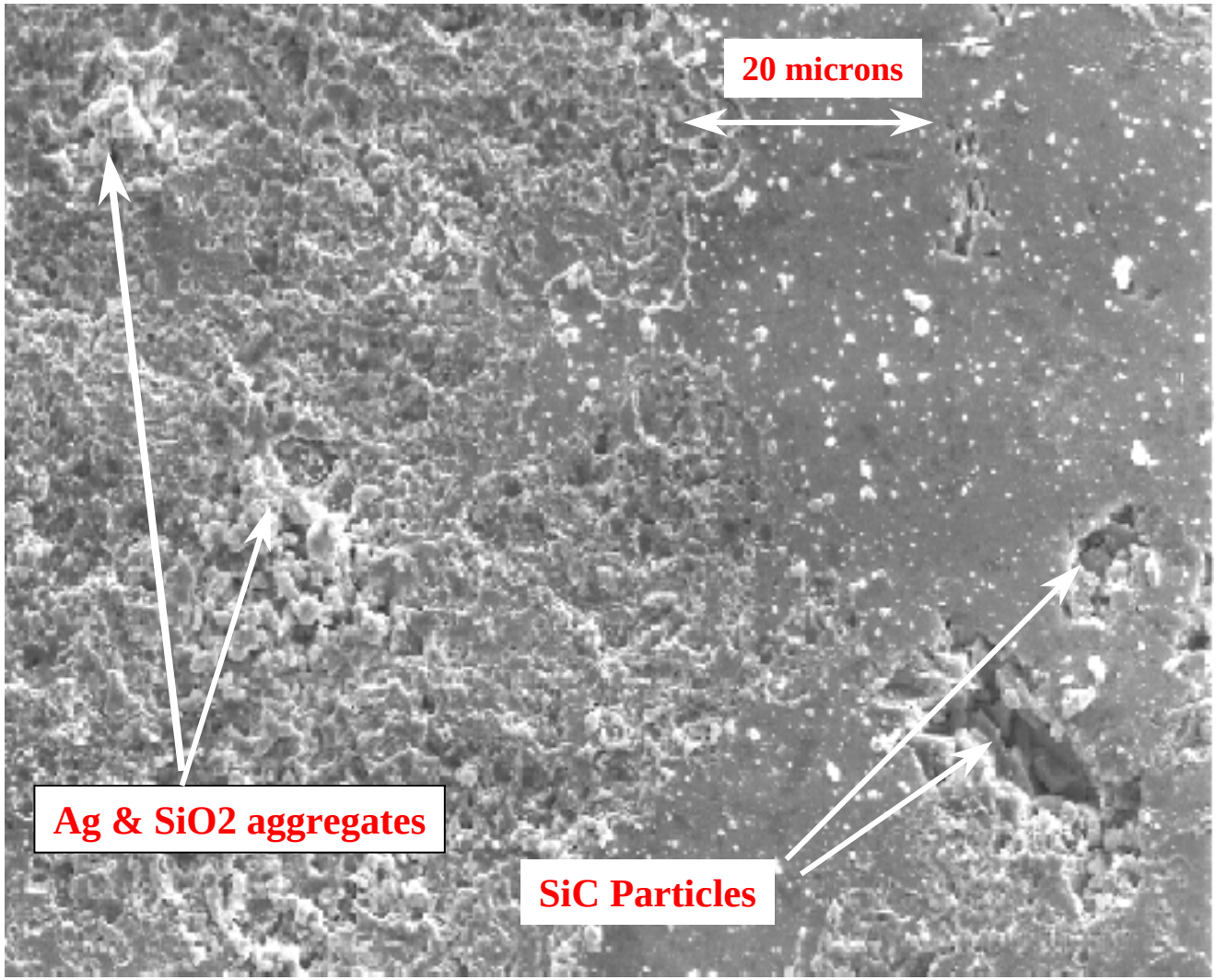
Common Contact Surface Specification Found on Drawings:

“Contact surface must be free of scratches and defects and have a mirror finish.”

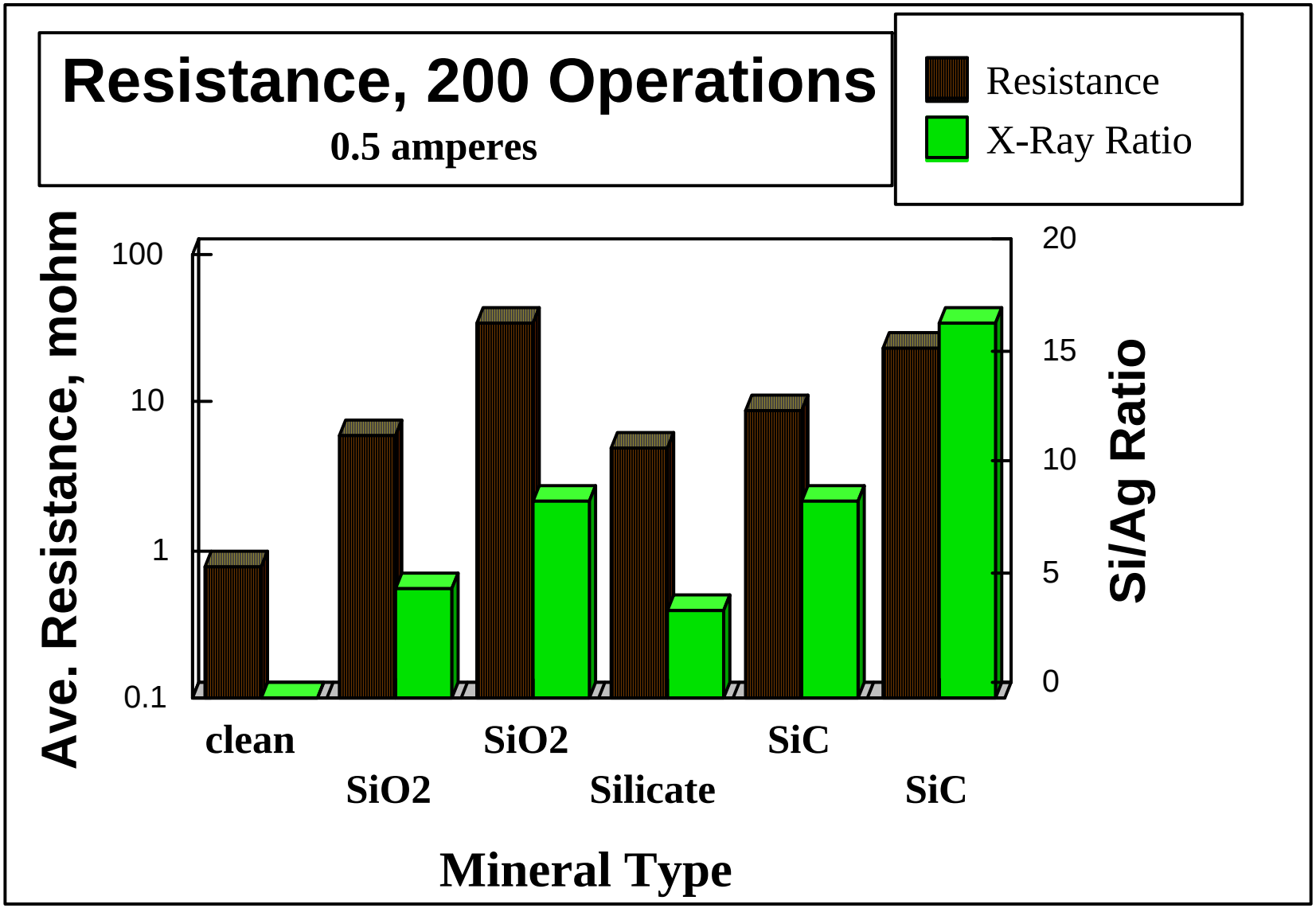
RESISTANCE VS. OPERATION NO.

0.5 Amperes



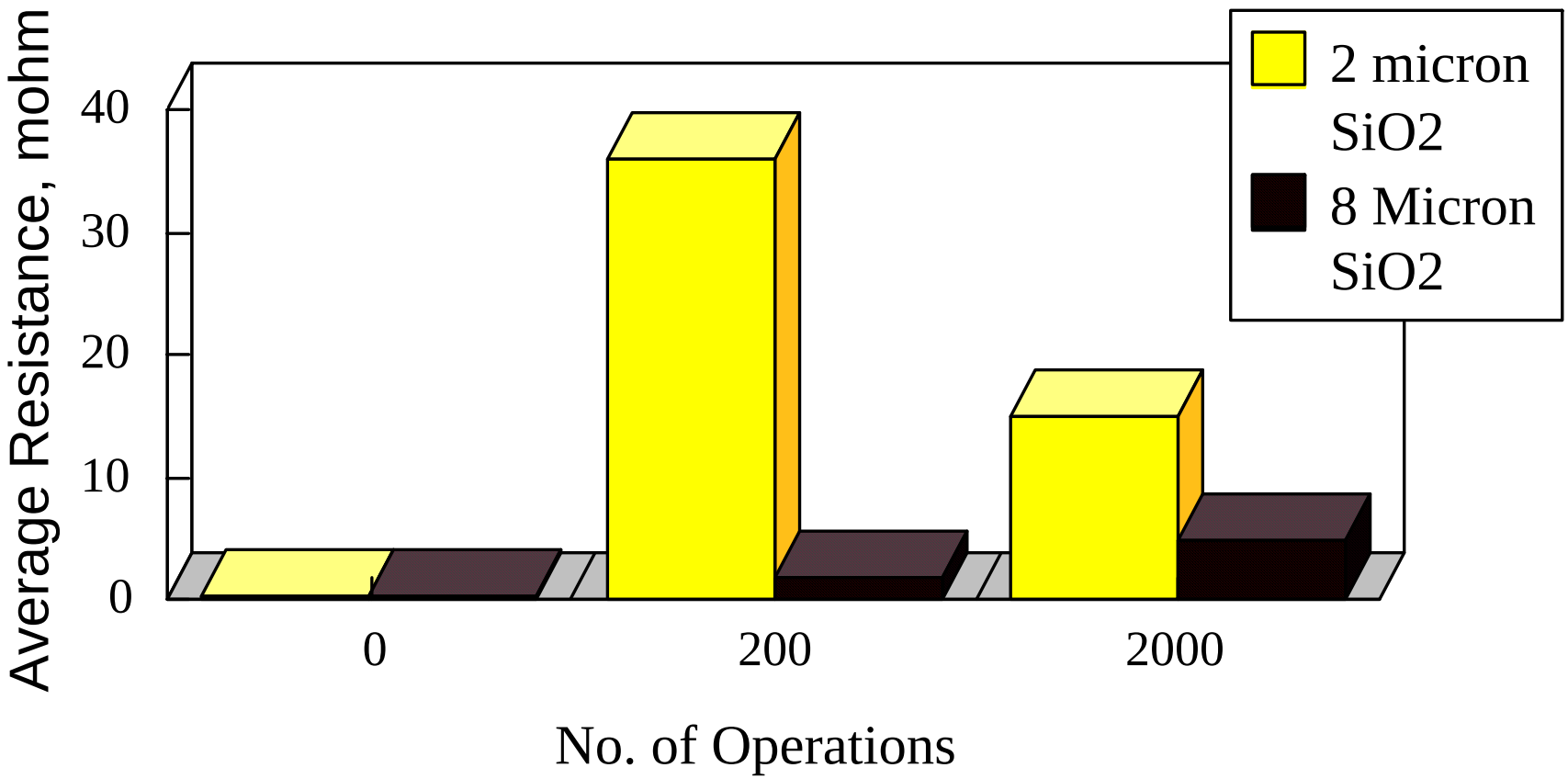


SEM Micrograph at edge of arced area after a single switching operation at 0.5 amperes and 120VAC.


Resistance, 200 Operations
0.5 amperes
Resistance
X-Ray Ratio
Ave. Resistance, mohm
100
10
1
0.1
20
15
10
5
0
Si/Ag Ratio
clean
SiO2
SiO2
Silicate
SiC
SiC
Mineral Type

Particle Size vs. Resistance

0.5 amperes



Particulate Summary:

1.Arcing increases surface roughness in terms of cavities and deposits which decreases negative effects for small amounts of insulator particulates.

2. Hard small mineral particulate can be embedded in the contact surface and even though they have no resistance effect before arcing, they can Increase resistance significantly after a few arcing operations.

3. Embedded grit from deburring and polishing operations form resistive aggregates on the contact surface that are similar in characteristics to thick film resistors.

4. Small amounts of particulate <40 µm in size normally aren't a problem for devices with > 0.3 Newtons force.

5. A few arcing operations should be employed before checking resistance.

Arc Reactions With Silicone Films

Bell Labs:

Germer, Gray, McKnight, Pharney and Others:

Low current, 48 volt, research on contact Switching

1. Developed Explanations For Organic Film Build Up On Contacts And The Activation Of the Contacts.

2. Showed the Initial Arc Plasma Chemistry Of The Arc Was Mainly Composed Of The Films On The Surface OF The Contacts.

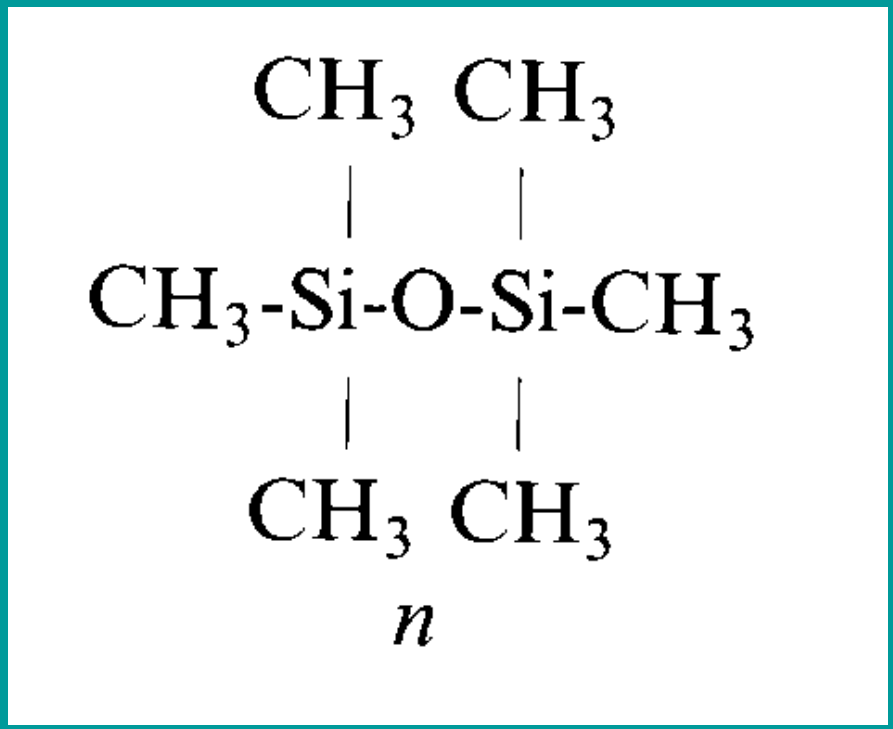
History

1959: First contact related paper: Moberly, Holm Conf.

1975: First significant paper on silicone migration, Bell Labs, Kitchen and Russell, Holm Conf.

1978 to Present: Witter, Lieper: Silicone migration studies & arc reactions, Holm Conf.

1993 to Present: Prof Tamai: silicone vapor deposition studies in sealed devices, Holm Conf.



Dimethyl Silicone Unit Structure, n is degree of polymerization

Silicone Spreading Rate as a Function of Viscosity

$$\ln \sigma = 0.65 \ln (1000/\nu) + 3.22$$

ν = viscosity in centistokes
σ = spreading rate = (cm)2 hr(-1/2)

Viscosity is Directly related to the Silicone Molecular Weight

Why Are Silicone Films Still A Big Problem For Contact Applications?

1. There are many sources for silicones: lubricants, mold release compounds, potting compounds, rubber seals, insulation sprays, cleaning compounds and more.

2. Silicone contamination is difficult to detect without using special expensive surface analysis equipment.

3. Electrical endurance testing used for approval of electromechanical devices will not detect silicone effects.

4. Silicone films combined with arcing can create very high resistive deposits on the contact surface.

Detection of Silicone Films

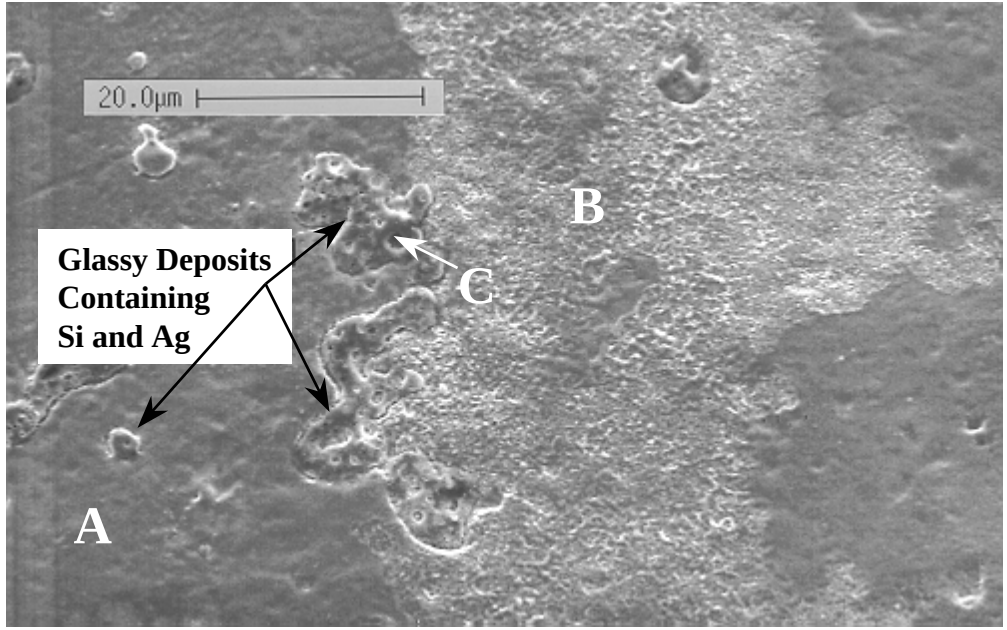
Silicone films are normally very thin, <50Å, (5 nanometers)

SEM with EDXA: analysis from roughly 1µm depth, (1000 nanometers), will not detect silicone films

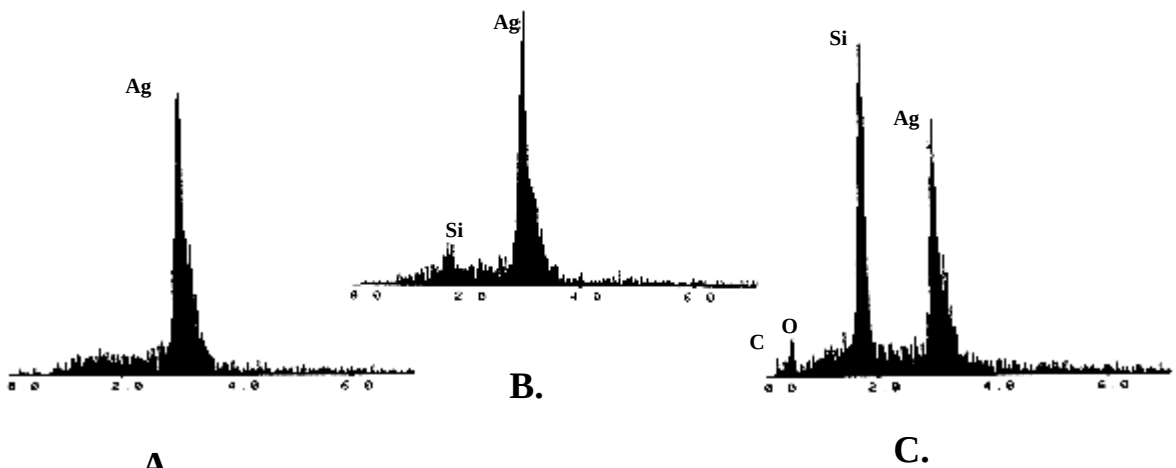
XPS (ESCA): Analysis from about 50Å depth, (5 nanometers), can detect very small amounts of silicone films

Auger Spectroscopy: Analysis depth similar to XPS

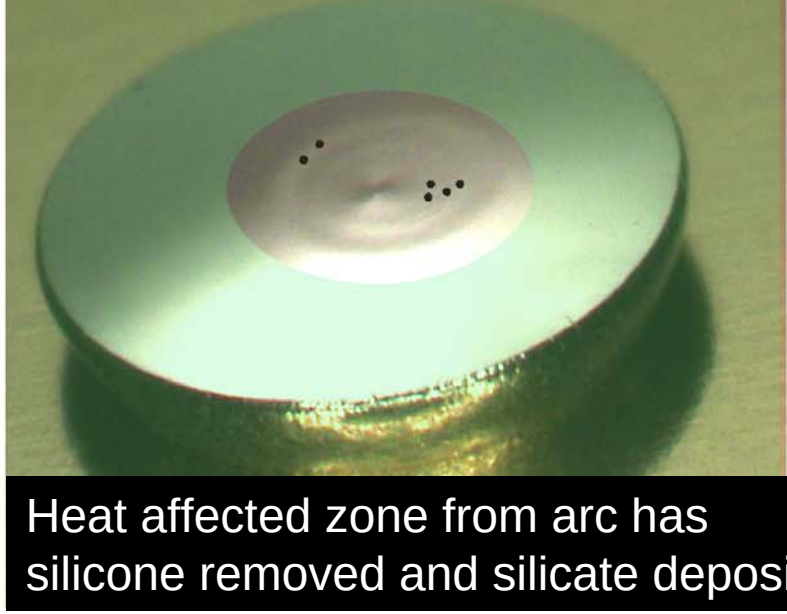
Arced Area After 50 Operations Showing Silicon Glass Deposits Near Edge Of Arced Area



SEM EDXA Spectra For Areas A, B, & Spot C In Figure 13



Green silicone film over all metal and contact.

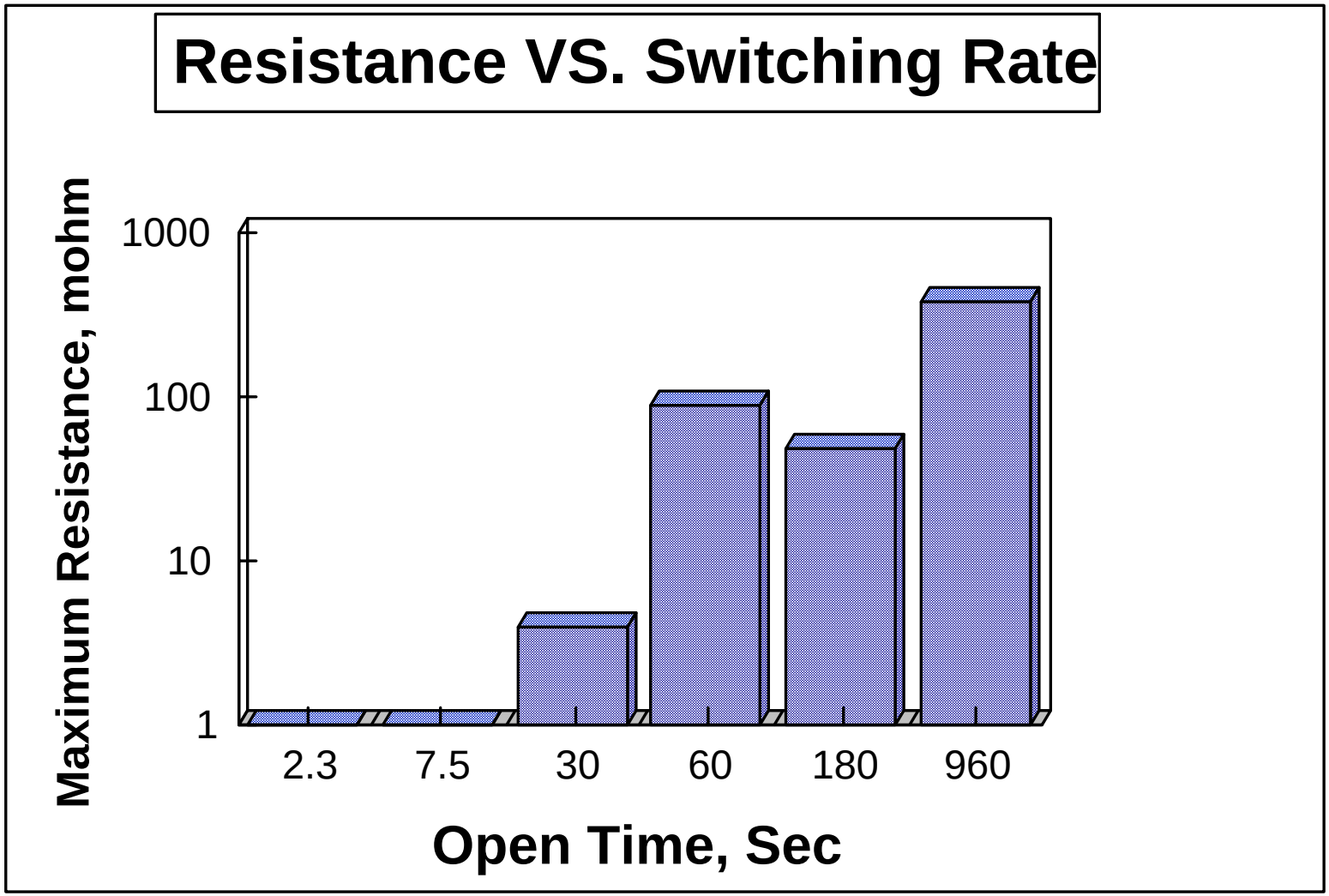


Heat affected zone from arc has silicone removed and silicate deposits.

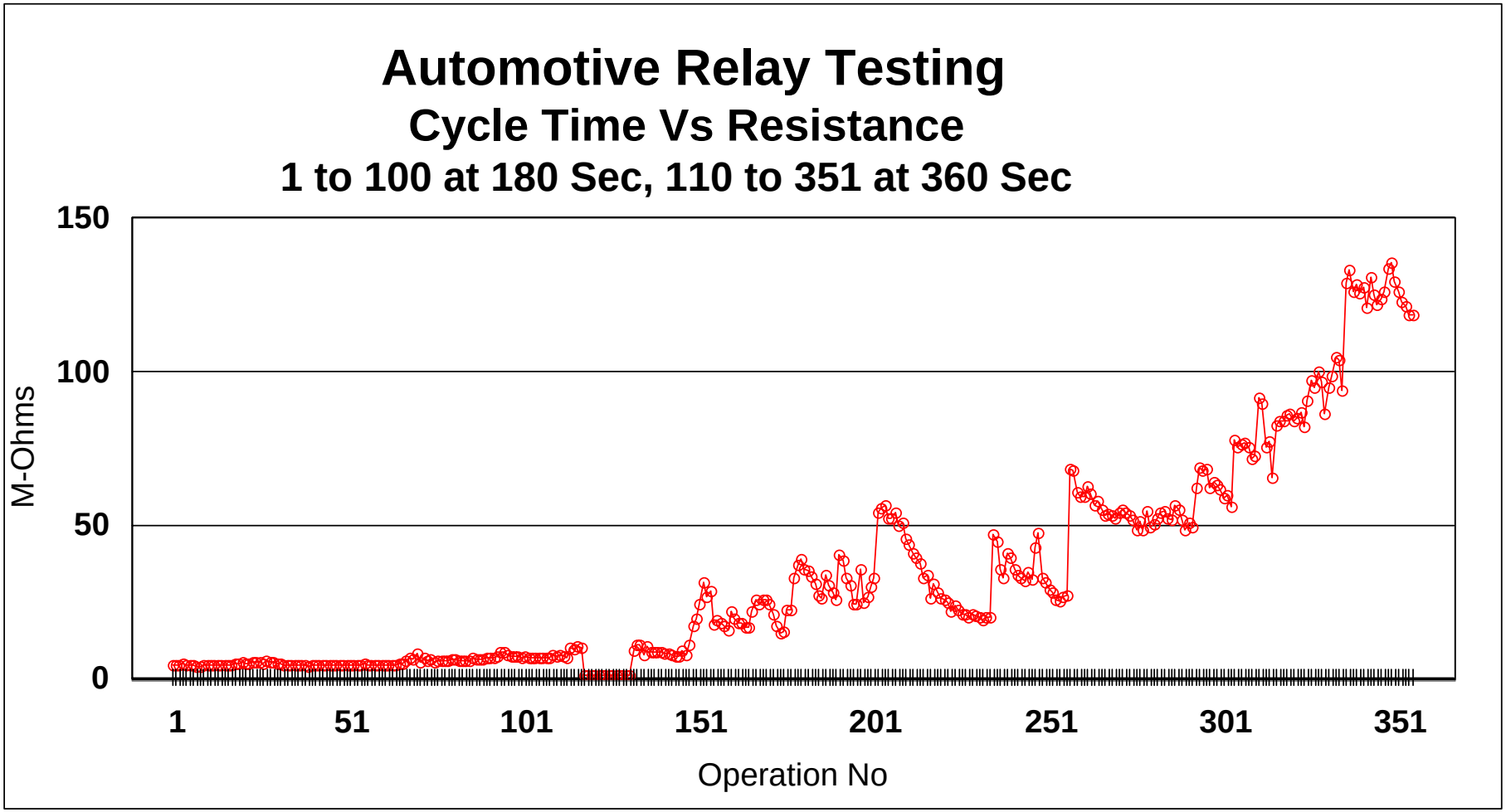
Silicone migrates inward to recoat the silicone depleted heat zone.

2nd Arc again depletes the silicone and deposits more silicate.

Arc Driven Migration Of Silicone

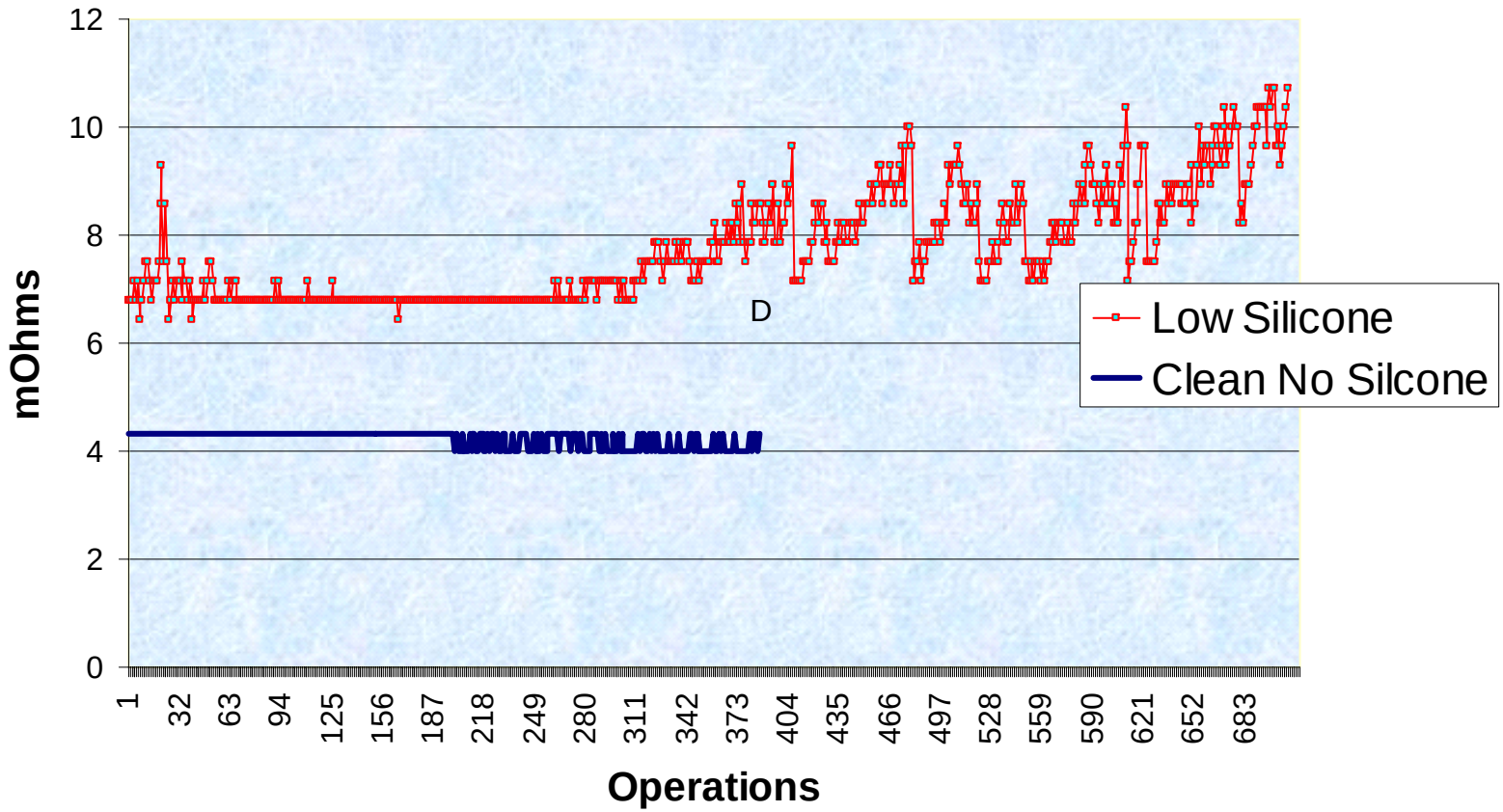


Silicone Coated Contacts Switched For 200 Operations At 0.5 amperes & 120VAC As a Function Of Time between Operations.

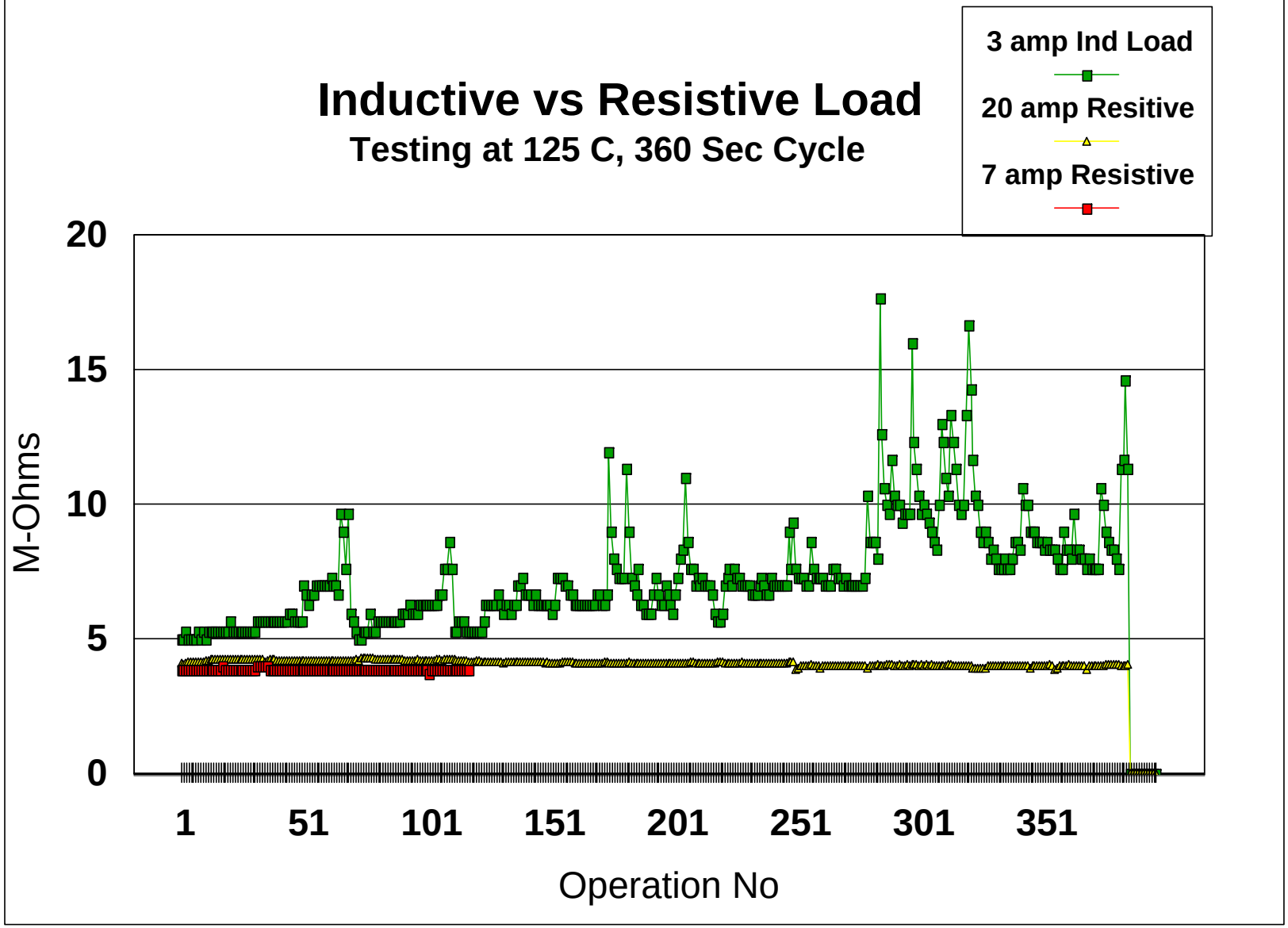


Automotive Relay, Silicone Contaminaition, Switching Rate vs. Resistance
Inductive Load, 3 amperes, 125C

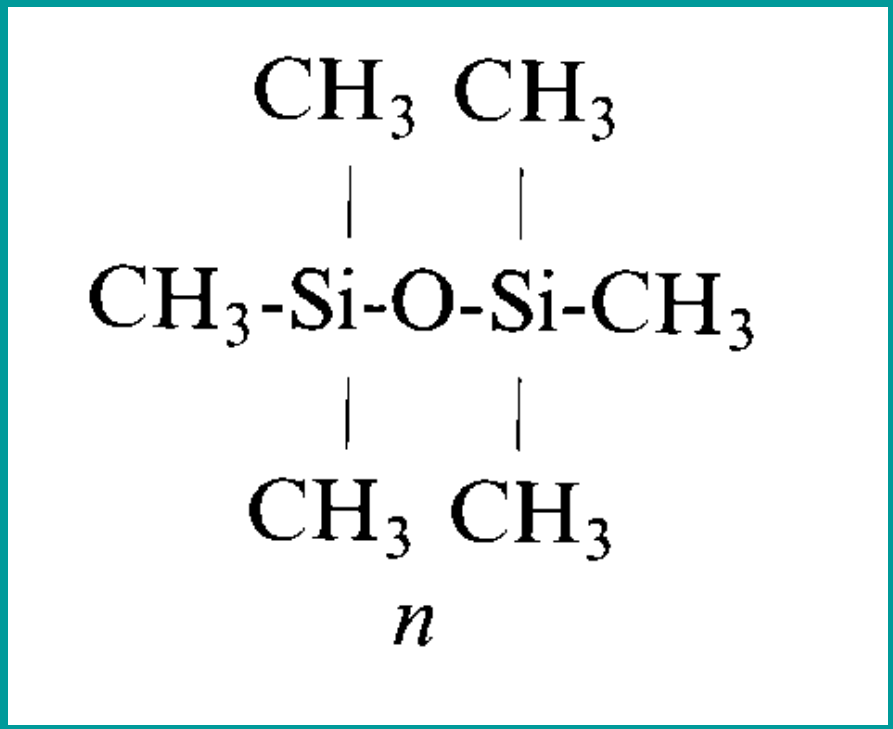
Automotive Relays
Low Si (~2%) vs No Si (<00.5%)
125C Inductive Load



Resistance Noise For Clean Relays vs. Low Contamination Relays



A comparison of silicone contaminated automotive relays switching inductive and resistive automotive loads.



Dimethyl Silicone Unit Structure, n is degree of polymerization

Silicone Film Conclusions:

1. Electrical Switching Tests Should Include A Series With Delayed Open Time To Detect Potential Silicone Problems.

2. The Formation of Silica or Silicates From Arc Reactions With Silicones Requires The Arc to Reach A Gaseous State.

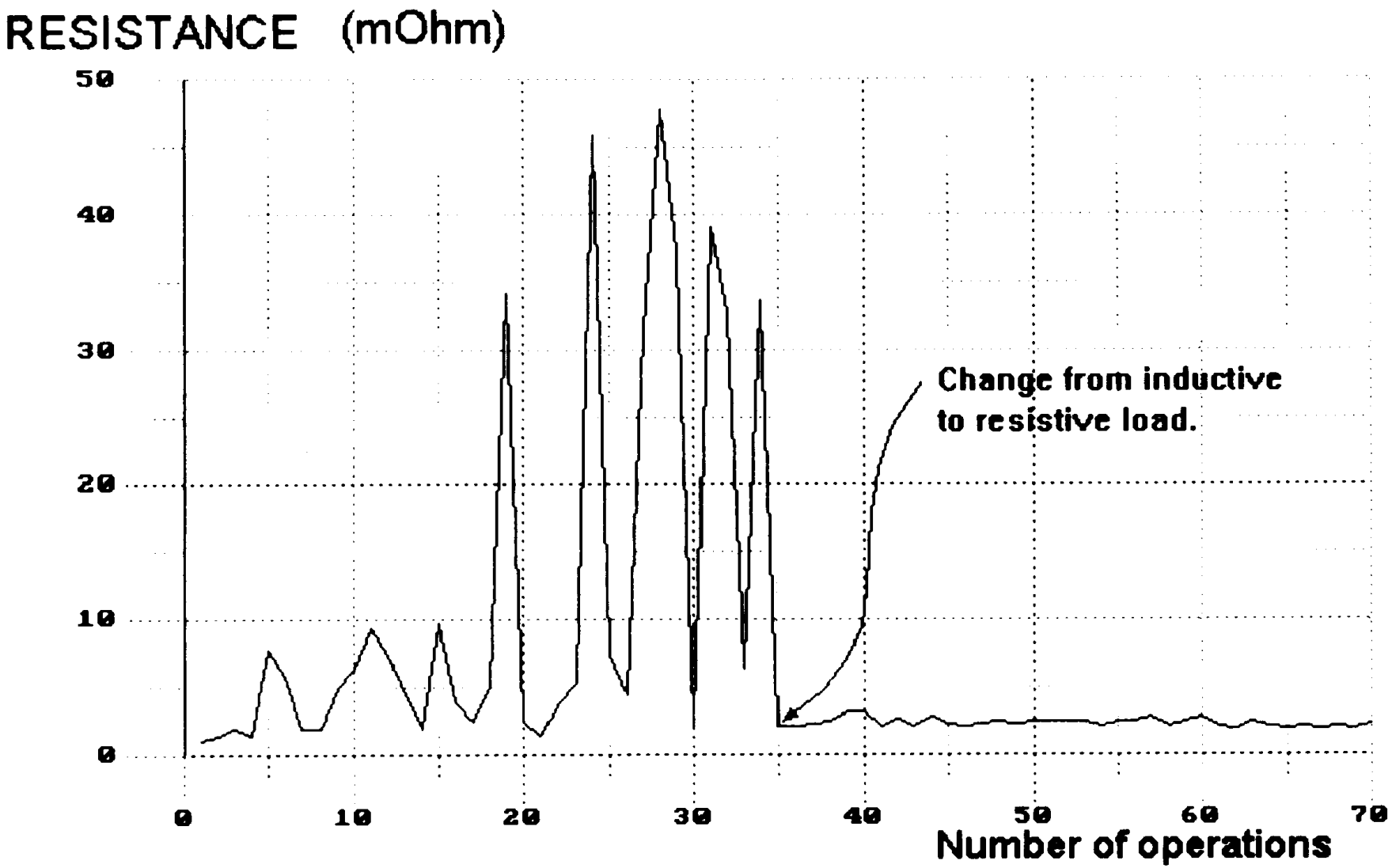
3. The Rate Of Testing Needed Depends On The Type Of Silicone In Terms Of Molecular Weight.

4. The Process Described As “Arc Driven Migration” Explains The Mechanism For Silica and Silicate Deposit Build Up During Switching.

5. If The Electrical Erosion Of The Contact Material Has A High Rate The Build Up Of High Resistance Deposits Will Not Occur.

Arc Reactions With The Contact Material Itself:

MATERIAL	WT. % AG	VOL. % AG	Vol% After Switching
AgCdO	85	81	70-80
$AgSO_2$	85	79	60-80
AgW	35	50	0-25


RESISTANCE (mOhm)
50
40
30
20
10
0
0
10
20
30
40
50
60
70
Change from inductive to resistive load.
Number of operations