# *Lab #1: Electrical Safety Testing*

Materials Required: Dale Model 601 Safety Analyzer; Electrical Fault Simulator.

## *Introduction:*

Electrical safety is an important issue for all equipment used in a hospital or other medical environment. There are several reasons why this is so. First, a hospital environment is much different than a home. In this environment patients wear much less electrically protective attire (such as shoes) than they would at home. This tends to make patients more vulnerable to electrical shock in a hospital than at home.

Second, most equipment uses AC power to operate, and this power source is extremely dangerous. The 60 Hz power coming from the wall outlets in the US is nearly optimal for inducing ventricular fibrillation. Less than 10 mA of 60 Hz current flowing through the chest can be fatal.

Finally, some equipment must be directly connected to a patient. This includes electrocardiographs, electroencephalographs, and similar machines. The leads on this type of equipment must be DC isolated from both earth ground and the commercial power system. The combination of a directly-connected patient lead and a failed equipment insulation system can be very dangerous.

The aim of this experiment is to familiarize you with the concepts of electrical safety testing by using the Dale model 601 Safety Analyzer. This is an industry-standard unit for checking the safety of patient equipment.

It's important to take this subject seriously, and understand it well. *The decisions you make based on your use of test equipment have life and death consequences*.

## *Failure Modes*

You have probably discussed these modes in class already, but here are some common failures often encountered in the field:

- Broken chassis ground wire. The metal chassis of all equipment normally connects to the building ground system through the ground pin of the power receptacle (green wire) This can allow the chassis to "float" to an undesired potential (for example, an internal short from the "hot" 120V connection can place 120V potential on the chassis in this case). This failure is tested by measuring the DC resistance between the ground pin on the power plug and the chassis. The NFPA limit is 0.15 Ω for new equipment, and 0.5 Ω for equipment in use. The UL limit is 0.1 Ω for new products.

- Grounded patient electrode. Patient electrodes should *float* with respect to ground; there should be no direct DC path to ground. This failure places the patient in danger if he or she is connected to the electrode and touches something that is energized (such as another piece of equipment that has a "hot" chassis).

- Hot patient electrode. Again, patient electrodes should be DC isolated from both the 120V mains and ground. An insulation breakdown can place 120V on the patient lead, directly exposing the person to the line voltage. If they contact a grounded object (such as a bed frame), the circuit will be completed. This is a very dangerous condition, since patient electrodes are designed to provide a low-resistance interface to tissue. Fatal levels of current can easily flow in this scenario!

- Electrode-to-electrode leakage. The electrode-to-electrode DC resistance should be very high ( $> 10^7\ \Omega$) to prevent this from happening, but occasionally an amplifier input stage may fail, or an input stage clamping diode may fail (these clamping diodes are present on EKG amplifiers to protect the input stage against the high-voltage pulse from a defibrillator). This failure usually exposes the patient to a relatively low (< 20 V) DC voltage, but because of the low-resistance skin electrodes, there is still a danger of direct tissue injury from burns, or other problems.

## *Fault Simulator*

In order to help you learn how to spot these problems, we've provided a simulator. This piece of equipment can replicate any of the above described problems, and more.

The simulator (Figure 1) plugs into the AC outlet of the Dale 601, and is programmed to malfunction in particular ways by moving the six toggle switches. When all the switches are in the "NORMAL" position, no failure is simulated and electrical measurements should be normal.

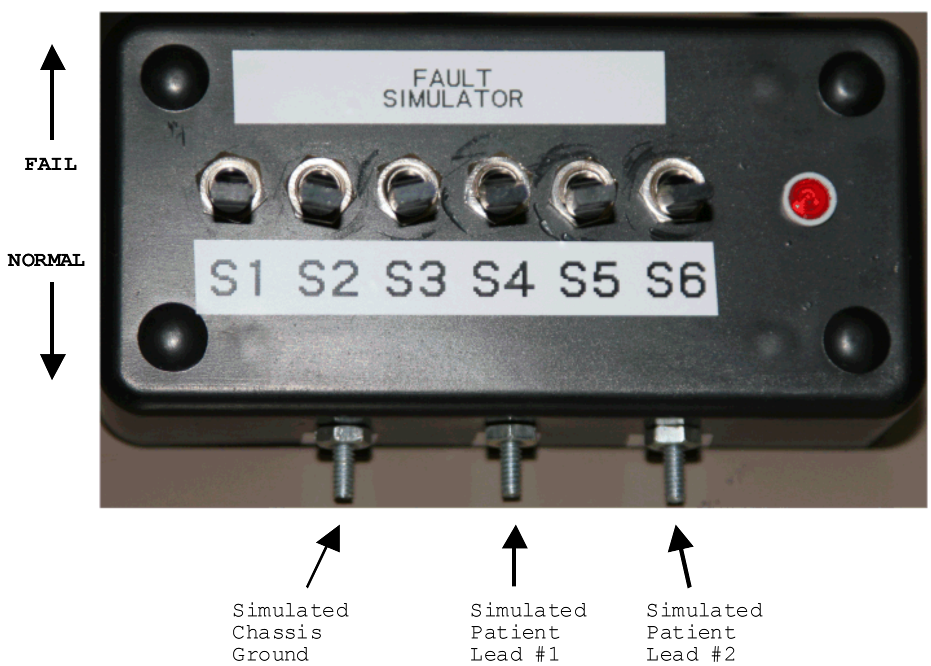


*Figure 1: Fault Simulator. All switches down mean no failure.*

Since the fault simulator produces real electrical malfunctions, you must treat it with caution! Full 120V line voltage (current limited to 0.5 mA for safety) may appear at any of the output terminals of the unit, depending on the switch settings. You should follow these precautions:

- Do NOT touch the terminal posts on the simulator when it is energized. The red POWER indicator alerts you to this condition.
- Do NOT connect the simulator to a person.
- Make connections to the simulator only through insulated alligator clips, and make your connections with the power OFF. Do not change connections with the power on.
- Do not use the simulator alone. Make sure a second person is present that knows how to turn off the power.
- If possible, precede the Dale 601 safety analyzer with a medical-grade isolation transformer.

## *Lab Procedure:*

1. Carefully read the Dale 601 Safety Analyzer manual. It is available on the instructor's web page (click the BMET-311 button). You should do this before coming to lab.

2. Perform the self-checkout of the Safety Analyzer. Follow the instructions in the Dale 601 operating manual pages 11-12. Report the pertinent results. (You may use an overhead projector as the "load" for the current test.)

3. Connect the Fault Simulator to the Safety Analyzer's outlet, then connect the Safety Analyzer to AC power. Make sure the OUTLET switch on the Safety Analyzer is in the center ("off") position. Energize the outlet only as instructed in the Dale 601 operating manual.

   a) Move the Fault Simulator switches to the "all normal" positions (S1=N, S2=N, S3=N, S4=N, S5=N, S6=N).

   b) Perform the DEVICE CURRENT, EARTH RESISTANCE, EARTH CURRENT, PATIENT LEAD LEAKAGE, PATIENT AUX CURRENT, and MAP tests as described on pages 19-23 of the Dale 601 operating manual pages. Report the pertinent results.

4. Set the Fault Simulator to: (S1=N, S2=F, S3=N, S4=N, S5=N, S6=N). Again perform the DEVICE CURRENT, EARTH RESISTANCE, EARTH CURRENT, PATIENT LEAD LEAKAGE, PATIENT AUX CURRENT, and MAP tests as described on pages 19-23 of the Dale 601 operating manual. Report the pertinent results as "FAILURE #1".

   Be sure to explain *what* is wrong with the measurements, and *what is physically wrong with the equipment.*

5. Set the Fault Simulator to: (S1=F, S2=F, S3=N, S4=N, S5=N, S6=N). Again perform the DEVICE CURRENT, EARTH RESISTANCE, EARTH CURRENT, PATIENT LEAD LEAKAGE, PATIENT AUX CURRENT, and MAP tests as described on pages 19-23 of the Dale 601 operating manual. Report the pertinent results as "FAILURE #2".

   Be sure to explain *what* is wrong with the measurements, and *what is physically wrong with the equipment.*

4. Set the Fault Simulator to: (S1=N, S2=N, S3=F, S4=N, S5=N, S6=F). Again perform the DEVICE CURRENT, EARTH RESISTANCE, EARTH CURRENT, PATIENT LEAD LEAKAGE, PATIENT AUX CURRENT, and MAP tests as described on pages 19-23 of the Dale 601 operating manual. Report the pertinent results as "FAILURE #3".

   Be sure to explain *what* is wrong with the measurements, and *what is physically wrong with the equipment. There are two failures in this step!*

5. Devise your own failure, and document it. Move the Fault Simulator switches to any combination of your choice and perform a safety analysis. This is FAILURE #4.

   Be sure to document your switch settings, as well as the failure analysis.

6. Bonus: You don't have to perform this step, but if you have time, you'll find it worthwhile. Using an ohmmeter, see if you can reverse-engineer the Fault Simulator and accurately draw its schematic diagram. (20 bonus points).

## *Lab Report #1 Checklist*

The lab reports in BMET-311 are formal, and for this experiment the following content (as a minimum) should be present:

- Cover page, with the experiment title, and names and *roles* of the team members. Don't forget to rotate roles for each experiment. (Refer to the course syllabus for more details).

- Introduction and Discussion of Theory: Present the theory behind this experiment; why is it important, what theories and ideas are being explored/tested, and so forth.

- Procedure: Discuss what activities your team performed during the experiment. Include recorded data as necessary, and show all calculations (use the equation editor to neatly incorporate mathematical formulas into the document). There should be discussion of the baseline condition (Step 3), and the four failure conditions.

- Conclusion: What can be concluded from the data you collected in the experiment? Please note that this is different than a summary (although it is okay to recapitulate or summarize what you did in the experiment as you reach conclusions).