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AECD-3787

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UNITED STATES ATOMIC ENERGY COMMISSION

DIAGNOSIS OF INSTABILITY OF AN ASSAY MASS
SPECTROMETER

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Photostat Price \$ 1.80
Microfilm Price \$ 1.80

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

March 6, 1946

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Oak Ridge, Tennessee

Technical Information Service, Oak Ridge, Tennessee

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(B-6.460.11)
AEC-3787

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DIAGNOSIS OF INSTABILITY OF AN ASSAY MASS SPECTROMETER

Introduction

The type of trouble most frequently encountered in maintaining an assay mass spectrometer falls into the general classification of unstable operation. When instability occurs, the major job usually consists of locating the cause, while the actual repair operations are relatively simple after the trouble has been properly located. This report deals solely with the systematic diagnosis and location of the cause of instability; however, a word in general about minimizing this trouble is in order. It has been found from many hours of operation and servicing experience that extreme care in carrying out every maintenance operation is the only satisfactory way of reducing instability problems to a minimum. This is especially important in source cleaning and alignment operations.

The chart, around which this report is written, illustrates the general practices followed in this laboratory. Because of the complexity of the instrument and because new causes of trouble occur occasionally, it must be remembered that any trouble-finding system incorporates a probability factor to take into account the occasional "freaks" and the complex troubles that are eventually traceable to a combination of causes.

Before proceeding with the system of diagnosis, it is necessary to check the operation of the electrometer circuits. The electrometers must be stable and must be functioning at normal operating sensitivity, since they are used as indicating instruments in search for the cause of instability.

Diagnosis

Consider the items from the top of the chart, going down the lefthand column first:

1.

INSTABILITY

Test for Type of Instability

The first thing to be determined is whether the beam is changing in intensity or in position. With a sample of hexafluoride in the instrument, the controls are set for standard slideback operation. The larger peak

679-2

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DATE 11-28-55

For The Atomic Energy Commission

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is dropped through the slit which is approximately 30% to 50% open, and is bucked out with the potentiometer. The electrometer control panels in this laboratory have been rewired so that the feedback meter indicates beam intensity when the potentiometer range switch is in position 4, 5 or 6 for slideback operation, making it possible to study the correlation of fluctuations of the galvanometer and the feedback meter. When both galvanometer and feedback meter rise and fall simultaneously, intensity instability is indicated, whereas, shifting of peak position will cause one meter to rise while the other drops. It must be remembered that the time constant for the feedback meter reading is not the same as for the galvanometer indication, which makes it necessary to study the correlation very closely, especially when the fluctuations are rapid.

Another method of determining the type of instability is to operate the instrument under conditions for making a feedback determination. With a sample of hexafluoride in the instrument, the 330 peak falls on the FP-54 collector plate and the 333 peak falls on the 954 collector. For the purpose of this test the slit need not be changed, i.e., if it is set for a 10% or a 100% "drop through," either condition will be satisfactory. After the feedback amplifier is checked for stability, the 330 peak is bucked out, using the precision potentiometer which is connected to the feedback amplifier, by turning the selector switch to "Null" and the range switch to "3." Preliminary adjustments and observations are made using low galvanometer sensitivity. When the sensitivity is advanced, any change in peak position will show up on the galvanometer. It is necessary to switch to "Zero-Null" to check the feedback amplifier because instability in this amplifier will cause the same effect. If the galvanometer remains steady under feedback conditions, it is obvious that both peaks are changing intensity simultaneously in proportional amounts, and the instability is then classed as "Intensity Instability."

This test may also be used with a fair degree of satisfaction on a single low mass peak, in which case the slit width should be so adjusted that the greater part of the total beam falls on the 954 collector plate. Actually then, the peak of the beam (the thin slice out of the middle) is being bucked out by the rest of the beam. In actual tests, this condition shows quite definitely whether or not the peak is shifting position. It must be borne in mind that the magnet supply may not regulate as well at low current and may contribute some shifting of peak position.

2.

INTENSITY INSTABILITY

Test Emission Regulator

The causes of intensity instability have most frequently been found in the source itself or in the emission regulator. They are occasionally found in the main control panel.

The operation of the emission regulator is checked at this point. The first item is to find out if the regulator is operating on the regulating range and possibly to shift operation to another position on the regulating plateau, as this has in a few isolated cases been found to help cure the instability.

The emission current and trap current are observed closely. Fluctuations in emission current almost always indicate trouble within the emission regulator or in the tube filament circuit. Trap current fluctuation may be caused by improper emission regulator operation or by a dirty source. Occasionally there will be trap current fluctuation in an instrument which is giving perfectly satisfactory service.

Quite often the trap current fluctuations and the intensity instability have been minimized by readjustment of the source magnet.

The grid voltage of the 6SJ7 tube, when measured with a vacuum tube voltmeter, will never be perfectly steady but should be constant to within 0.1 volt.

Oscillation is tested for by connecting an oscilloscope through a 0.1 mfd condenser to the case lead, the other terminal of the oscilloscope being connected to ground. A small 60-cycle peak of approximately 0.1 volt is normal.

IT IS IMPORTANT THAT THE HIGH VOLTAGE BE TURNED OFF WHILE MAKING ANY VOLTAGE MEASUREMENTS IN THE NORMAL WAY ON THE EMISSION REGULATOR.

3.

SOURCE OR MAIN CONTROL PANEL

Test Source Leakage

If the emission regulator has been found to be satisfactory, the source is tested for electrical leakage. The commercial volt ohm megger insulation tester that is used measures up to 1000 megohms while applying 500 volts (through a protective high resistance).

The resistance from every source element to every other source element is measured with the tube leads disconnected from the main control panel. Leakage of the order of 500 megohms from case to ground or from focus to ground is considered serious. In many cases this may be eliminated, or sufficiently minimized, by disconnecting the tube leads at the main control panel and applying a Tesla spark coil to each of the individual leads to break down the leakage path. Great care must be exercised, as excessive sparking will puncture the small source insulators. Leakage from a beam center plate to ground may not be serious if that particular plate is

grounded during operation. Leakage from ion repeller to case is not considered to be very serious as in this laboratory the ion repeller is operated, with only few exceptions, at case potential. However, leakage in the case often indicates dirty source. Leakage from filament to case is usually serious.

4.

DIRTY SOURCE OR MAIN CONTROL PANEL

Test Voltages to Tube Elements

A source is said to be "dirty" when sufficient sample has been run through it to cause a layer of material to form in the case. This deposit is believed to be capable of carrying a charge and of exhibiting all of the unpleasant properties of a film of semi-conducting material, upsetting the stability of the electrical fields. It may be pointed out that if the source plates are not cleaned properly a similar type of film may accumulate there which gives the same effect. This differentiation between dirty source and leaky source should be remembered for the discussions throughout this paper.

A simple test instrument found to be useful in studying small voltage fluctuations of a high voltage supply is described as the "R-C Tester." (Report by G. P. Happ and A. E. Cameron, "Use of the 'R-C' Tester," November 14, 1945.) This instrument consists merely of a high resistance and capacity in series, which is connected across the high voltage output. Small fluctuations show up as a voltage developed across the high resistance and are read by a vacuum tube voltmeter. This R-C tester is used to check the stability of voltages to the tube elements. EVERY SAFETY PRECAUTION MUST BE USED, AS HIGH VOLTAGES ARE INVOLVED. A fluctuating voltage which appears even when the tube element is disconnected indicates that voltage delivered by the main control panel is not stable.

It is supposed that at this point of the diagnosis no shifting of peak position was found. Therefore, any voltage fluctuation must originate in a section of the main control panel or the output leads, for if the potential across the entire main control panel was fluctuating it would cause a shift of peak position as in scanning.

If the voltages from the main control panel have all been found to be constant after following the chart to this point, there is a very high probability that the source has seen sufficient sample material to have become dirty, and a clean source is recommended.

5.

PEAK POSITION INSTABILITY

Test Case to Ground Voltage

If the tests mentioned under the heading "Instability" indicate a shifting of peak position, the first test is to determine whether or not the high voltage is stable. The R-C tester is very convenient to use in observing the stability of the case to ground voltage which should be constant to within 0.1 volt at approximately 2000 volts. CAUTION: HIGH VOLTAGE! Subsequent tests to be used in the event of high voltage instability will be discussed under the heading "High Voltage Line-Up."

6.

MAGNET SUPPLY, SOURCE, FOCUS, OR BEAM CENTER

Test Magnet Supply

If the case to ground potential is found to be steady, the magnet supply is tested, preferably by means of a built-in R-C tester, described in the report "Use of the 'R-C' Tester," by G. P. Happ and A. E. Cameron. The vacuum tube voltmeter is connected to a telephone plug which is inserted into the closed circuit jack. When the meter is disconnected the 20 megohm resistor is shorted out and the 1 mfd condenser serves as an additional filter. This test should show less than 0.01 volt fluctuation for normal operation. Magnet supplies not equipped with a built-in R-C tester may be tested with an external R-C tester. EVERY SAFETY PRECAUTION MUST BE USED, AS HIGH VOLTAGE AND HIGH CURRENT ARE INVOLVED.

Another test that may be used to check large fluctuations of the magnet supply is the observance of the grid potential of the 6SJ7 control tube, using a vacuum tube voltmeter. This test is not generally used in this laboratory because it is not sensitive enough to indicate small fluctuations.

7.

SOURCE, FOCUS, OR BEAM CENTER CIRCUITS

Test Source Leakage

If the magnet supply is operating satisfactorily at this point, there is a high probability that the peak shifting is being caused by fluctuation of a beam center or focus plate potential as a result of source leakage, poor contact or unstable potential across the respective sections of the voltage divider system in the main control panel.

Electrical leakage between source elements is investigated as outlined in Section 3. If source leakage is causing the peak shift, it may be detected by a voltage fluctuation as read by the R-C tester on case, focus, or beam center. CAUTION: HIGH VOLTAGE! However, the 500-volt insulation tester is always used for final detection of leakage in the source.

A punctured insulator in the source probably will not be detected by using the 500-volt insulation tester, but may be detected by ear when the high voltage "pops" across or it may be indicated when the voltage actually fluctuates. Many of the high voltage breakdowns encountered have been detected visually. It is possible that such a breakdown will not be detectable by any of these means and will be found only when the source is removed after exhausting other tests on the instrument.

8.

BEAM CENTER, OR FOCUS

Test Focus and B. C. Voltages With Tube Disconnected

The R-C tester is used to observe voltage fluctuations of the beam center and focus leads to the tube with the tube disconnected. CAUTION: HIGH VOLTAGE! Obviously, if fluctuations appear when the tube is disconnected, the supply is fluctuating and the main control panel is further investigated.

9.

FOCUS OR BEAM CENTER IN THE TUBE

Test Focus and B. C. Voltages With Tube Connected

If the focus and beam center voltages have been found to be stable with the tube disconnected, then the voltages are observed with the tube connected. CAUTION: HIGH VOLTAGE! Instability of the voltages under this condition indicates either source leakage or high voltage breakdown in the tube or in the tube leads. However, if the voltages do not fluctuate, then there may be a poor contact to a focus or beam center plate which would cause unstable operation of the instrument.

10.

HIGH VOLTAGE LINE-UP

Test Output of High Voltage Supply

Going back now to Section 5, if the case to ground voltage was unstable as indicated by the R-C tester, the cause of instability was to be sought in the high voltage line-up, and the course of that search is now to be indicated.

672 - 7

The R-C tester is used to check the stability of the output of the high voltage supply while it is isolated from the main control panel. CAUTION: HIGH VOLTAGE! The use of a dummy load in place of the main control panel is often helpful while making this test and is essential when testing the high voltage relay. The variation should be less than 0.1 volt at 2500 volts.

Another method of testing the high voltage supply is to observe the voltage fluctuation of the grid of the control tube, using a vacuum tube voltmeter. This test is regarded as less sensitive and generally less indicative than the R-C test.

11.

MAIN CONTROL PANEL, EMISSION REGULATOR OR SOURCE

Test Case to Ground Voltage With Tube Disconnected

If the high voltage supply has been found stable, the potential between the case lead and ground is observed with the tube elements disconnected. CAUTION: HIGH VOLTAGE! If the R-C tester shows fluctuations on this test, it is an indication of trouble in the main control panel or emission regulator panel. However, if no fluctuations are observed, the trouble is probably in the source.

12.

SOURCE

Test Source Leakage

The source should be tested for leakage as described in Section 3. If the source is free from electrical leakage, there is a great probability that there is high voltage insulation breakdown in the source. It is possible that a dirty source may give the same indication, especially if there is a deposit on any of the focus plates, but a dirty case usually causes intensity type of instability.

13.

MAIN CONTROL OR EMISSION REGULATOR TO GROUND LEAKAGE

Test Case to Ground Voltage With E Cable Out

If fluctuations have been found in test 11, the E cable is disconnected and the R-C test applied to the potential between ground and the point on the main control panel divider which supplies the case potential. CAUTION:

672-8

Page 8

HIGH VOLTAGE: If this test shows a steady potential, the trouble is in the emission regulator or the cables; whereas, if the test shows that fluctuations exist here, the trouble is obviously in the main control panel.

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March 6, 1946

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INSTABILITY TRACING CHART

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