December 19, 1986
ENG. 51:4

Notes on DYNALYZER HVU Usage

1. It has been shown that the Dynalyzer HVU gives accurate reproduction of tube waveforms for almost all applications. Possible cautions.

   a) kV frequency response is "good" (relatively flat) out to 100 kHz (10 µsec). Remember some tube kicks are faster than 10 µsec, some scopes (especially digital ones) may not clearly display fast events on a slow scan. One competitive divider with "poor" response accentuated high frequency events by a factor of ~10 and showed kicks not visible with the Dynalyzer. (It may be possible for the calibration department to duplicate this if required.)

   b) mA frequency response is "good" (relatively flat) out to 1000 Hz (1 msec). There could still be an mA "phase shift" of ~ 250 µsec which might be important on very short exposures.

   c) The filament sensing transformer is in the common leg of the filament circuit. It will not read DC currents. It will read incorrectly if both filaments are energized simultaneously. This occurs in some R/F generators which keep the large filament warm during fluoro. This may also occur by design or by accident in other machines. The filament output voltage will also be erroneous if the unused filament is shorted to (in parallel with) the common lead.

2. A Digital Voltmeter can be used with the HVU to measure FLUORO mA and will work accurately on the DC volts range - provided that the mA output is "zeroed" as it should be. A standard DC voltmeter is not sufficient for the filament, where RMS data is desired or for the kV, where peak reading is normally desired.

3. The Fluoro and Rad mA circuits of the tank are subject to drift over temperature and time. A typical correction might involve only about 1 mA, but errors as large as 10 mA are not unheard of. Use a scope or a meter (not the Digital Display!) to set the zero prior to every measurement session where low mA levels or critical measurements are recorded.

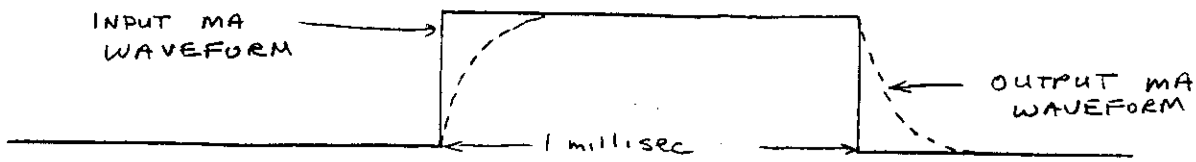
4. Many people asked questions regarding the use of the Dynalyzer with "High Frequency" systems.

   a) I know of no problems in using the HVU or Display with H.F. transformation to High Voltage. I think our answer should be roughly as follows:

   "The kV freqency response (± 1 db @ 100,000 Hz) and the mA frequency response (± 1 db @ 1000 Hz) refer to the relationship of output voltage to input voltage with an AC signal applied. One effect of the higher frequencies used in more recent x-ray equipment is to reduce the ripple on the kV and mA waveforms. Since this makes the waveform more like DC during the exposure, the AC frequency response is not an issue for the bulk of the exposure".

   "When operated at lower mA's most high frequency systems have very fast kV rise times. At higher mA's they have very fast kV fall times. The Dynalyzer, with its exceptional kV response, can track these waveforms better than anything else available" (to my knowledge).

"The mA response of the Dynalyzer is not nearly as good and can change a 1 millisecond exposure as follows:



This delaying or "shifting" of the mA signal should be taken into account when viewing HVU mA output on the scope, and when using the Digital Display. When measuring the mA for very short exposures (under 10 msec) it is best to use the mA trigger feature. That way, the part of the mA waveform which is seen after the kV goes to zero is included in the mAs measurement. The error caused by this mA "shift" becomes less and less important as exposure time increases, and can be ignored for most routine situations". (See previous memo regarding the danger of trying to reduce the information in a whole waveform one or two representative numbers.)

b) There have been problems related to High Frequency (and DC) filament circuits. These problems relate to:

- The insertion loss (resistive) of the extra cable and connections whenever the cathode side of the HVU is added to the High Voltage circuit.

- The insertion loss (inductive) associated with the current sensing "doughnut" transformer.
- The inability of the AC doughnut to track DC filament current.
- The fact that the current is sensed in the common leg of the filament circuit. This causes a problem in cases where both filaments may be energized simultaneously (e.g. some generators maintain a standby current on the large focus while doing fluoro with the small focus).

The second problem, negligible for most systems, can become a problem as the frequency of filament exitation increases, if the filament is "voltage controlled". (Neither the first or second is a problem if the filament is "current controlled" - that is, where the filament is regulated based on feedback from a filament current sensing circuit.)

In cases where the insertion impedance is not negligible, the old technique of using the anode end only for final mA calibration is still recommended.

c) The frequency response of the Display is such that it will accurately track the kV, mA and filament output from the HVU.

Notes on DIGITAL DISPLAY Usage

1. The Digital Display reduces all of the information contained in a x-ray exposure into several numbers. It is the user's responsibility to understand the Display operation and the waveform sufficiently to insure that these numbers are meaningful.

   a) The kV displayed is the highest value seen during the entire measurement. The longer the exposure the less representative this number is. For example, a spike at the beginning of the exposure, or a 20 µsec kick during the exposure can change the PKV dramatically.

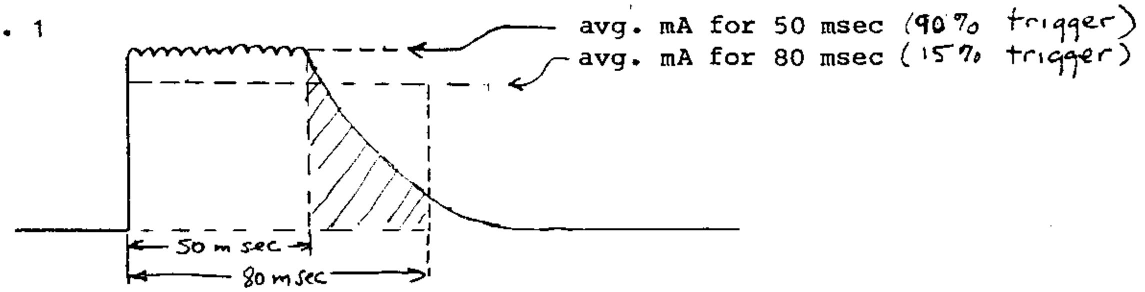
   b) The mAs is the true integration of the mA output over the "measured part of the exposure". Note that the trigger level, and the waveform may substantially effect the "measured part of the exposurs". Generally, the longer the exposure, the more representative the mAs - this is because the triggering effects are a smaller percentage of longer exposures.

   c) The mA is the mAs divided by the measured exposure time. Note: The trigger level used is very important when measuring short exposures.

   d) The Display reads the true RMS value of the filament current and the "line" voltage. When measuring the "line drop" caused by an x-ray exposure, use at least a 65 msec exposure to allow the RMS to DC converter to settle.

2. When making mA or exposure time measurements with low mA or capacitive filtering of kV, a substantial variation in the mA reading can occur due to waveform/trigger level interaction.

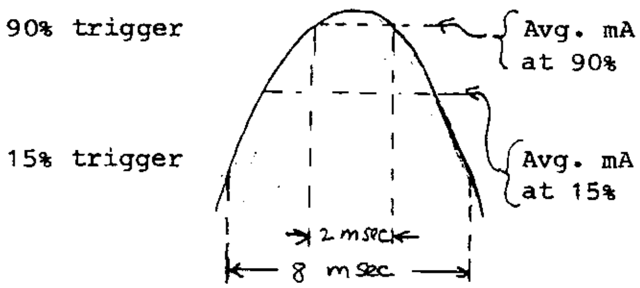
FIG. 1



With the generator set for a 50 msec exposure, and the waveform shown in figure 1, if the trigger level is set high (90%) the mA will be integrated for 50 msec. With the trigger level set low, it will be integrated for roughly 80 msec. When the average mA is calculated, since the cross hatched area has a reduced value, the displayed mA for low trigger will be almost 20% less than for the high trigger value.

NOTE: As exposure time increases, the low average will rise (at 1 second there is only a 1.5% discrepancy). This could appear as though the mA was changing with exposure time!

3. When measuring very short (single phase) exposures: The displayed exposure time will vary with trigger level.



Most people don't realize that the mA will also vary with trigger level, and can read about 50% high at 90% trigger.

4. Percent trigger mode sets the trigger level to a selected percentage of the previous exposure.

   a) When the reset button is pushed, the trigger level goes to a very low value. This can cause the next shot to be very different than expected.

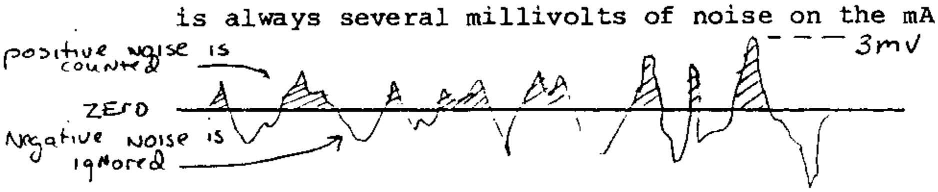
   b) When using PERCENT and kV (mA) trigger and the kV (mA) is decreased from the last shot, the Display may not be triggered. For example, if the Display is set for 75% kV, and an 80 kV shot follows a 120 kV shot, the Display will not trigger. 80 kV does not exceed the trigger threshold of (75% of 120 =) 90 kV.

   c) On critical measurements it may be best to take a test exposure every time Reset is pushed, the trigger level is changed or technique is changed.

5. When using low mA (mammo or Fluoro) techniques, I would recommend using the Dynalyzer on the FLUORO range (20 mV per mA). This can be used up to 500 mA theoretically.

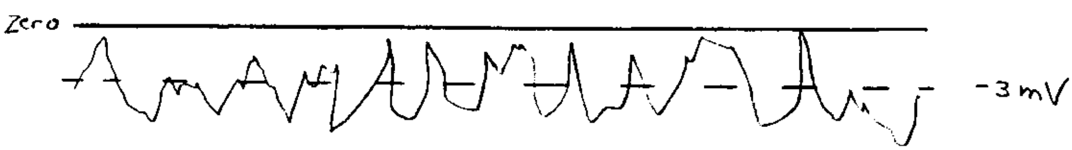
   CAUTION: On the Fluoro range, the Display's mAs counter overflows at 131 mAs and terminates the exposure measurement!!

6. Do not use the Display to set the zero level of the Rad or Fluoro mA tank outputs. The internal V to F converter "see" only positive voltages. There is always several millivolts of noise on the mA line:



With no mA applied the display will count the positive noise as mA.

If the zero control is adjusted to where the Display reads 0 mA, it means that the tank has been offset so that the highest noise peak is still not positive. It will now take roughly 3 mA of signal to read just the noise peaks.



Application Note - Fluoro mA Measurements

Most x-ray generators use a common method for measuring x-ray tube current. The meters typically used, including digital mAs meters, are of the "mid-center" type (installed between the high tension transformer secondary windings). These cannot be relied upon to give accurate readings in fluoroscopic situations: errors caused by leakage currents and stray capacitances, which account for only a small percentage of total mA for radiography, account for a much higher proportion of total mA for fluoroscopy. These errors can arise from a number of sources:

- power supply diode leakage currents (solid state diodes only),
- power transformer "false" (capacitive) currents,
- currents through bleeder resistors (installed in some generators), and
- currents through both built-in and external kV dividers.

In addition, the metering circuit is often in a hostile electrical environment, with transient voltages present. This makes the circuit susceptible to component failure, such as short-circuited meter diodes. Shorted diodes cause less current to be seen by the meter, with no otherwise obvious malfunctioning. The metering circuit should always be checked periodically.

The only accurate way of determining tube current is by means of an "aerial" monitoring device, such as the Dynalyzer High Voltage Unit, inserted in the cathode circuit as close as possible to the x-ray tube. The "mid-center" meter gives improper readings because it responds to the sum of the diode leakage currents,transformer false currents, tube current and cable (charging) current. To minimize these effects, one (or all) of the following methods should be used:

NOTE

Before measuring the tube current using the Dynalyzer High Voltage Unit*,the offset (zero) of the mA circuitry must be verified and, if necessary, adjusted by means of the appropriate "zero adjust" potentiometer on the front panel just prior to use. This is especially true when using the Dynalyzer II High Voltage Unit, but is also applicable to the Dynalyzer III as well. (The Dynalyzer III has a 20 mV/mA range for flouroscopy; the Dynalyzer II only a 1mV/mA range. This 20-fold difference in sensitivity makes the Dynalyzer III more immune to the effects of offset voltages.) An offset of 1 millivolt (instead of 0.000) could cause a 5% error at 1 mA on a Dynalyzer III but would be 100% for a Dynalyzer II. (The offset is adjusted by connecting a digital voltmeter to the mA BNC output of the High Voltage Unit and turning the "zero adjust" potentiometer until the voltmeter reads 0.0000 on the most sensitive scale.)

* To eliminate the effects of cable capacitance when there are long cable lengths between the x-ray generator and the x-ray tube (which could make the tube current appear higher by 5-30% on single-phase) the Dynalyzer H.V.U. should be inserted in the circuit at a point close to the x-ray tube.

If an oscilloscope is to used with the H.V.U instead of the Dynalyzer Digital Display to measure the fluoroscpic mA, greatest accuracy will be assured if the set-up described below is used, especially with single phase x-ray generators. This will eliminate the need to calculate the average value of the waveform. (A dual channel or dual beam oscilloscope, with polarity reversal capability on the vertical inputs is required.)

a) Connect coax cable from "mA" BNC connector of H.V.U. to a BNC "T" connector.
b) Connect one end of BNC "T" to channel "A" of scope.
c) Using a short coax jumper, connect the remaining end of the BNC "T" to channel "B" of scope.
d) Set channel "A" to "DC Coupled".
e) Set channel "B" to "AC Coupled, Inverted".
f) Set the mode selector on scope to "Add A+B".
MA can now be determined by measuring the amplitude of the waveform above the baseline.

Some x-ray systems exhibit a condition sometimes referred to as "ringing". This is characterized by the mA waveform going negative (below the base-line) between positive cycles. The setup described above will eliminate the error seen when calculating the average mA from this waveform. This "ringing" can cause the displayed value (on the Digital Display) to read low. Since the Digital Display responds to positive mA, the negative excursions of the waveform will not be subtracted properly. It is for this reason that a scope should be used when "ringing" is present. It is still possible to use the display in this case by temporarily offsetting the "zero" (on the H.V.U.) in the positive direction until the lowest excursion of the ringing waveform is positive - then subtracting this amount from the displayed mA. For example, if the mA waveform goes negative by 8 mA (worst case), one would offset the zero to +10 mV and subtract 10 mA from the display for a Dynalyzer II H.V.U. or, if a Dynalyzer III is used on the fluoro range, one would subtract 0.5 mA*

Another method which may be helpful in the presence of "ringing" or other unusual waveforms is to connect a D.V.M. (digital voltmeter) to the mA output of the H.V.U.. Although D.V.M.s differ in their response to varying waveforms, generally good correspondence can be expected among the D.V.M., the Dynalyzer Digital Display, and an aerial meter.

* If a Digital Display II is used as the indicating device in conjunction with a Dynalyzer III High Voltage Unit, one must remember to divide the displayed mA by 20 in order to obtain the actual tube current whenever the H.V.U. is set to the low mA ("fluoro") range.