FLUKE®
Biomedical

35080B

kVp Divider

Operators Manual

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Fluke Biomedical
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Section 1
General Information

1.1 Introduction

The Model 35080B kVp Divider is an alternative to high-voltage divider tanks. It provides a safe, non-invasive, fast measurement of kVp without endangering personnel and/or equipment. Its use is primarily intended for x-ray machine service and calibration.

High-speed precision logarithmic circuitry allows for wide variations in mA and distance without a sacrifice of accuracy or response speed. The Model 35080B kVp Divider provides an analog output voltage proportional to the instantaneous voltage applied to the x-ray tube. When the kVp divider is connected to a storage oscilloscope, the kV waveform may be viewed directly. If a digital display of the kVp value is desired, then the Model 35080B kVp Divider may be connected to the Model 35050A Dosimeter/kVp Readout.

One Wide Range Filter Pack (37617) allows high-accuracy measurements from 50 to 150kV. The kVp divider is placed on the x-ray table with the filter pack in place. A storage oscilloscope is connected to the kVp divider. The x-ray beam is collimated to the area of the filter pack. An exposure is made and the kV waveform is displayed on the storage oscilloscope. At no time are the high-voltage supply cables disturbed.

The Model 35080B kVp Divider is highly portable -- a contrast to bulky, heavy high-voltage divider tanks. The instrument is accurate to ± 2%, exclusive of linearity and filtration effects.

The user should note, however, that as with an invasive divider, the accuracy of readings will depend on the accuracy of the oscilloscope or readout device used in the measurements.

1.2 Manual Addenda

Any improvements or changes concerning the instrument or manual will be explained in an addenda included with the manual. Be sure to note these changes and incorporate them into the manual.

1.3 Safety Symbol and Terms

The following symbol and terms are found on the instrument or used in this manual.


The symbol on the instrument indicates that the user should refer to the operating instructions located in the manual.

The WARNING heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The CAUTION heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1.4 Specifications

Range
50-150 kVp with the Wide Range Filter Pack (37617)

Accuracy
± 2% of reading, exclusive of linearity, filtration, and gain effects

Calibration
Internally-generated signal provides a calibration check

Permitted Tube Current Range
1 mA to 3000 mA, dependent on waveform and distance

Response Time
150 microseconds 10-90%

Environment
Operating temperature 15° to 35°C; storage temperature -35° to 50°C; relative humidity to 90%

Orientation
The long axis of the Model 35080B kVp Divider is oriented perpendicular to the axis of the x-ray tube to eliminate heel effect.

Table 1-1. Permitted Tube Current Settings (less than ± 1 kV effect)

	Single-Phase Half - Wave	**Single-Phase Full - Wave**	**Three-Phase**
Minimum Tube Current (12" Focal Spot to kVp divider)	1 mA	2 mA	4 mA
Maximum Tube Current (22" Focal Spot to kVp divider)	750 mA	1500 mA	3000 mA
Factory calibration performed at 200 mA, 2.5 mm Al inherent filtration, 22 inches focal spot to kVp divider. Six-point calibration check.			

Batteries
One Eveready 9V alkaline type 522; life approximately 60 hours; BATTERY CHECK function connects battery to output connector for voltage measurement.

Dimensions and Weight
60 mm high x 210 mm wide x 90 mm deep

(2-3/8 in x 8-1/4 in x 3-1/2 in) net weight 0.68 kg (1-1/2 lb)

Standard Filter Pack
One Wide Range Filter Pack* (37617) is provided for measurement from 50 to 150 kVp.

Table 1-2. The Wide Range Filter Pack (37617) Specifications

Range: 50 to 150 kVp
Sensitivity: 0.1 V/10 kV
Cal: 0.400 V
Zero: 40 kV
Cal: 80 kV
Accuracy: ± 2% exclusive of linearity and filtration effects
Linearity and filtration effects can be corrected using curves from Section 2 of this instruction manual.

Optional Filter Packs

A Test Filter Pack (32863) that provides verification of instrument accuracy, a K-edge Mammo Filter Pack (37355)* and a Linear Mammo Filter Pack (37351) used for precision measurements from 22 to 40 kVp, a CT Filter Pack (33551) used for CT system kVp measurements from 70 to 140 kVp, a Mobile Filter Pack Plus (37946) used for measurements on x-ray systems with kV waveforms above 1 kHz with substantial ripple, and a Low Range Filter Pack (38237) used for measurements from 30 kVp to 90 kVp where the kVp range or sensitivity of other filter packs is not adequate.

** Patent numbers 4,843,619 and 4,916,727*

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Section 2
Operation

NOTE

Prior to taking measurements with the Model 35080B kVp Divider, it is suggested that the battery and internal calibration be checked.

2.1 Battery Check

Connect the output of the Model 35080B kVp Divider to a DVM (digital voltmeter). Place the kVp divider function switch in the "BAT CHK" position. The battery should be replaced if the voltage is less than 7.0 volts as the remaining battery life is quite short. The battery must be replaced if the voltage is less than 6.5 volts as the instrument will not function properly when the voltage supply is below this minimum level.

2.2 Internal Calibration Check

Connect the output of the Model 35080B kVp Divider to a DVM with ± 0.1% accuracy. Remove any filter pack that may be inserted in the kVp Divider. Turn the function switch to the "CAL" position. After a short delay, a voltage of 0.750 ± 1% will appear. This reading verifies the stability of the kVp Divider ratio electronics. A 1% error in the kVp Divider gain will cause a maximum kV reading error of 0.75% of reading. Refer to Section 10.4 for detailed information on calibration.

2.3 Filter Pack Selection

One Wide Range Filter Pack (37617) is provided as standard for the Model 35080B kVp Divider. See Sections 4 through 9 of this manual for use of optional filter packs available from Fluke Biomedical, Radiation Management Services.

2.4 Oscilloscope Zero and Offsets

NOTE

It is assumed that the operator is familiar with the use of a storage oscilloscope. The following examples are for oscilloscopes with 8 major divisions for vertical scales and sensitivity selections of 0.1 V/div and 0.2 V/div. The selection of time scales or triggering are not discussed in this manual.

Figures 2-1A & 2B show suggested oscilloscope settings for the 50-150 kV range using the Wide Range Filter Pack (37617).

1. Insert the Wide Range Filter Pack (37617) into the Model 35080B kVp Divider and connect the kVp divider to the oscilloscope.
2. Set the oscilloscope gain to 0.1 V/div, DC Coupled. This setting corresponds to a 10 kV/div sensitivity.
3. If making kV measurements from 50 to 120 kV, set the FUNCTION switch of the kVp divider to the OFF position and adjust the oscilloscope vertical position control so that the oscilloscope trace coincides with the bottom horizontal line on the screen, which corresponds to 40 kV. Then set the FUNCTION switch of the kVp Divider to the "CAL" position and verify that after a delay of several seconds the trace on the oscilloscope coincides with middle horizontal line on the screen, which corresponds to 80 kV. When switching to the "RUN" position, a slight offset may be noted on the oscilloscope. Do NOT readjust the oscilloscope trace to compensate for this offset. Refer to Figure 2-1A.
4. If making kV measurements from 120 to 150 kV, set the FUNCTION switch of the kVp divider to the "CAL" position and adjust the oscilloscope vertical position control so that the oscilloscope trace coincides with the bottom line on the screen, which corresponds to 80 kV. Refer to Figure 2-1B.

NOTE

If the accuracy of the Model 35080B kVp Divider is in question, the output voltage may be checked with a ± 0.1% DVM. The proper CAL voltage is on the filter pack label. The allowed tolerance is ± 1%. A 1% error will cause at most a 0.75% error in the kV reading.

1A)

120 kV			
110 kV			
100 kV			
90 kV			
80 kV			CAL at 80
70 kV			
60 kV			
50 kV			
40 kV			ZERO at 40

Sensitivity 10 kV/div
Scope setting 0.1 V/div

1B)

160 kV			
150 kV			
140 kV			
130 kV			
120 kV			
110 kV			
100 kV			
90 kV			
80 kV			CAL at 80

Sensitivity 10 kV/div
Scope setting 0.1 V/div

Figure 2-1A and 1B. Suggested Oscilloscope Settings for Use with the Wide Range Filter Pack (37617)

As an alternative to reading directly in kV, the output of the Model 35080B kVp Divider may be read directly in volts. The formula below is used to calculate the kV:

kV = Model 35080B voltage x 100 + ZERO kV

Example: A peak voltage of 0.300 volts is read. The ZERO kV of the Wide Range Filter Pack (37617) is 40 kV. Therefore:

kV = 0.300 x 100 + 40
= 30 + 40
= 70 kV

2.5 Geometry of Setup

The filter pack is aligned on the beam center, with the long axis of the Model 35080B kVp Divider perpendicular to the x-ray tube axis, and the beam normal to the tabletop (see Figure 2-2). The x-ray beam must be large enough to cover the active area of the filter pack. Distance is not critical, but a 22-inch distance from focal spot to kVp divider is suggested.

The kVp divider must be inverted for under-table x-ray head evaluation (refer to Figure 2-3). Again, the filter pack should be on beam center, perpendicular to the axis of the x-ray tube and the beam normal to the table. The beam area must be large enough to cover the active area of the filter pack.

In positioning the kVp divider, the long axis of the instrument should be perpendicular to the x-ray tube axis to eliminate “heel effect.” The beam must strike the filter pack side of the kVp divider; the unit is designed to be turned over for under-table x-ray heads. In setting the x-ray generator, 200 mA at 22 inches is recommended, but the limits of operation allow higher or lower settings and distances. Refer to Section 1-4, Specifications, for low current limits.

After correctly positioning the kVp Divider, connect the oscilloscope, place the kVp Divider in the “RUN” mode and make an exposure.

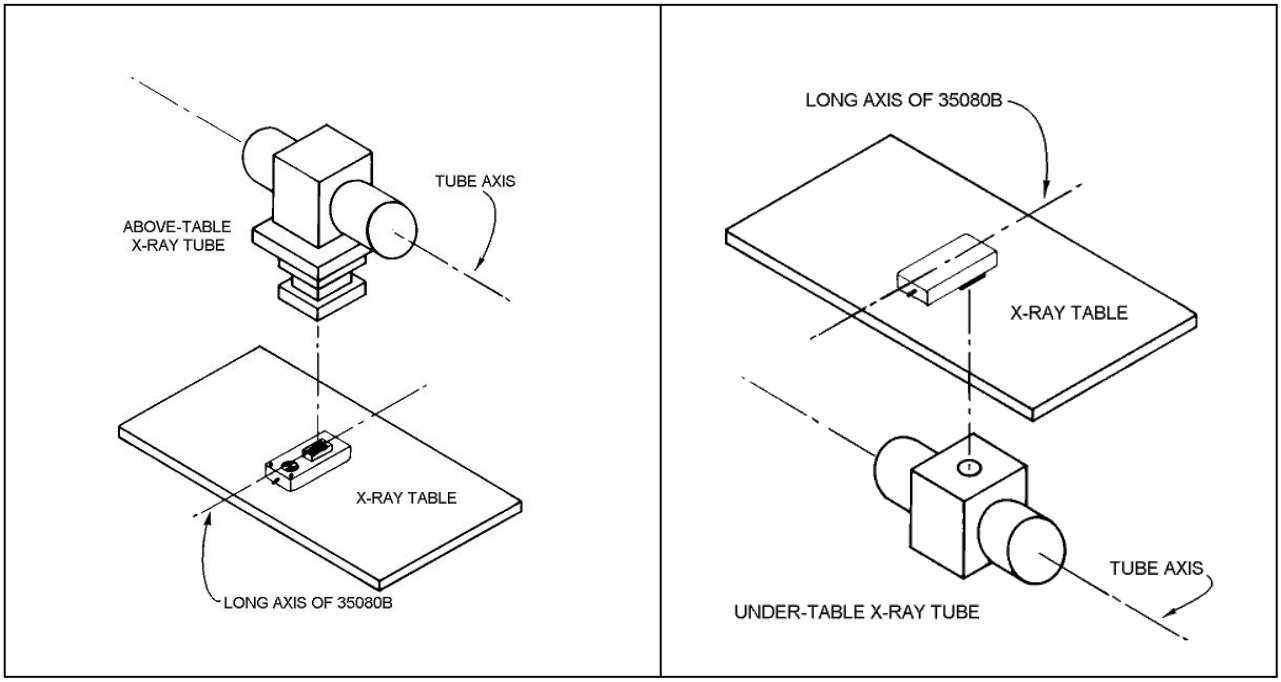

Figure 2-2. Geometry of Setup for Above-Table X-ray Tube

Figure 2-3. Geometry of Setup for Below-Table X-ray Tube

2.6 Filtration Effect Corrections

Corrections for filtration are made with the correction curves in Figure 2-4. Factory calibration of the Model 35080B kVp Divider is performed with 2.5 mm Al total filtration, so any other amount of filtration in the beam which is greater than or less than 2.5 mm Al will require some correction of the apparent reading.

Example: Suppose the kVp Divider reads 90 kV, using the Wide Range Filter Pack (37617). The x-ray machine has 5.0 mm Al total filtration. The filtration effect curve for this filter pack indicates a filtration effect of 0.5 kV per mm Al at 90 kVp. To determine the actual reading, the filtration in the x-ray machine is subtracted from the standard calibration filtration (2.5 mm Al) and the resulting number is multiplied by the filtration effect: (2.5-5.0) x 0.5 = -1.25 kV. The resulting number, -1.25 kV, is the correction which is added to the apparent reading. Therefore, the actual reading is 90 kV + (-1.25 kV) = 88.75 kV.

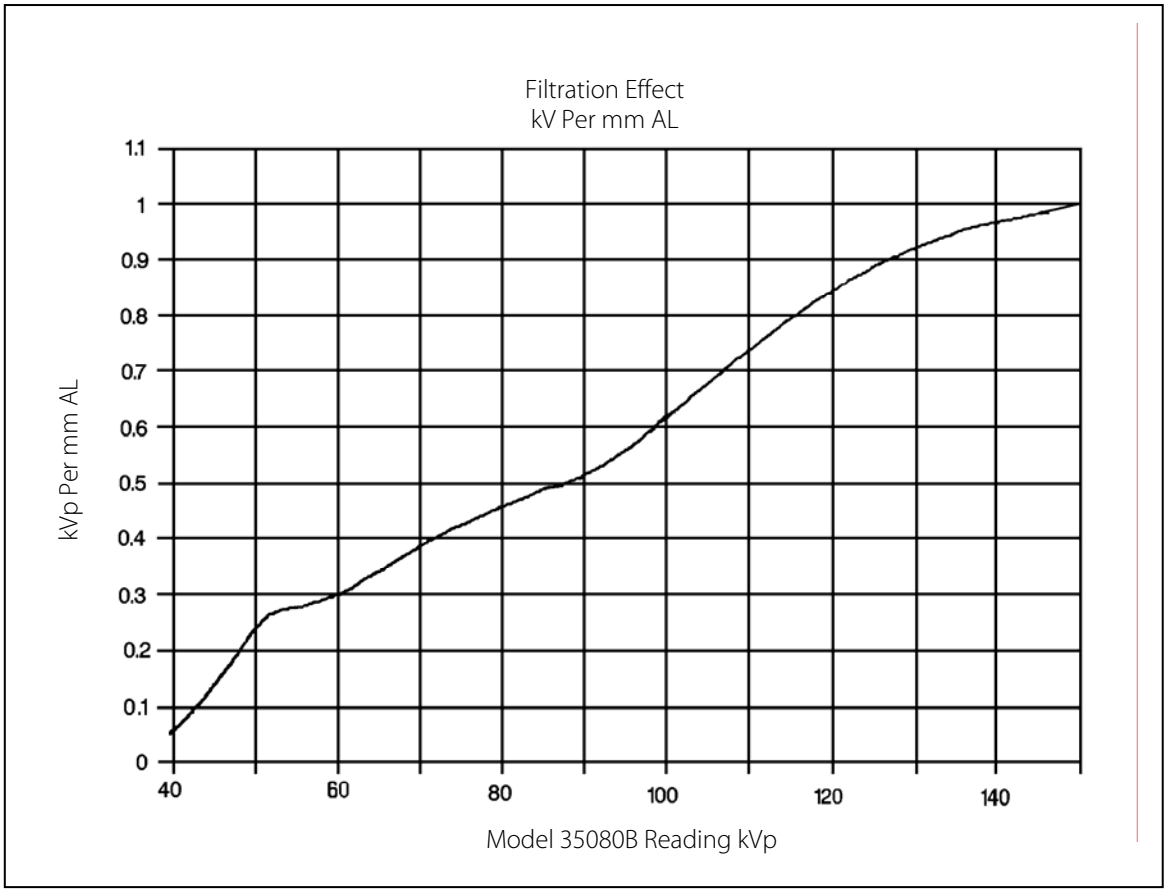

Figure 2-4. The Wide Range Filter Pack (37617) Filtration Effect Correction Curve

2.7 Linearity Corrections

Corrections for linearity in using the Wide Range Filter Pack (37617) are made by taking the apparent output of the Model 35080B and adding (or subtracting) the value in kV shown on the following curve. For the greatest accuracy possible, readings should first be corrected for filtration before linearity corrections are made. For most applications, however, linearity corrections alone may be adequate, especially if the difference in total filtration from the calibration standard of 2.5 mm Al is small. See Section 2.6 for information about filtration correction.

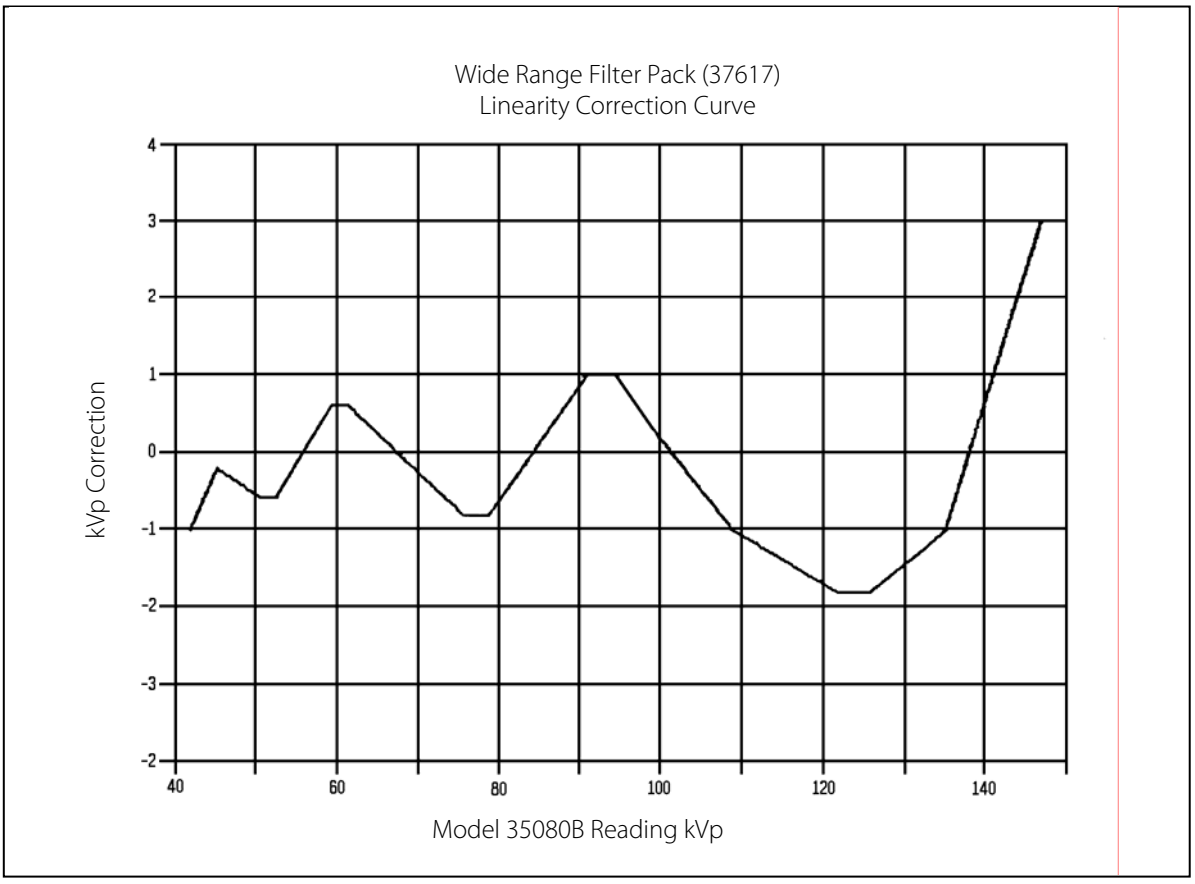

Figure2-5. *The Wide Range Filter Pack (37617) Linearity Correction Curve. The kVp Correction Value read from the vertical scale should be added to the Model 35080B kVp Divider reading to produce the corrected kVp result.*

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Section 3
Theory of Operation

3.1 Introduction

When used with the Wide Range Filter Pack (37617) the Model 35080B kVp Divider produces an output voltage that closely follows the voltage applied to the x-ray tube. It does this with a 10-90% response time of 150 microseconds, so the waveform can be used not only for determining kVp, but also for making precise time determinations and for diagnosing generator malfunctions.

3.2 Measurement Theory

In this measurement scheme, two x-ray detectors are used (refer to Figures 3-1 and 3-2). The x-ray beam passes through a relatively heavy filter prior to striking detector A, and through a lighter filter prior to striking detector B. The ratio of the currents (I/I) is transformed to a voltage by a custom-designed ratio module.

Typically, this ratio voltage increases as the voltage applied to the x-ray tube increases. The ratio voltage is virtually independent of the current applied to the x-ray tube and the distance to the x-ray tube.

3.3 Wide Range Filter Pack (37617)

The Wide Range Filter Pack (37617) is a standard filter pack supplied with the Model 35080B kVp Divider. This filter pack gives linear performance over a wide 50-150 kVp range. Detailed characteristics of the filter pack are given in Section 1, General Information, and Section 2, Operating Instructions, of this instruction manual.

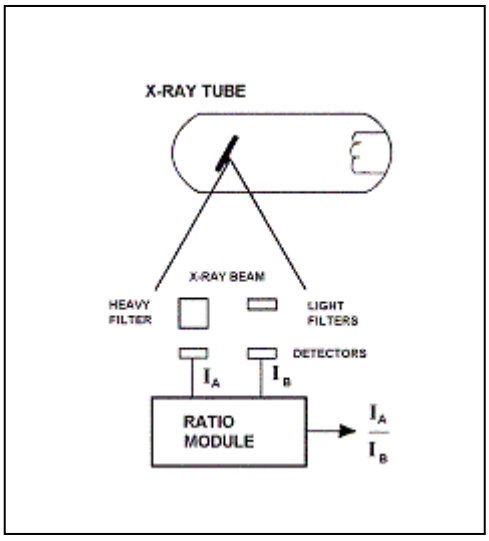

Figure 3-1. Simplified Functional Block Diagram of the Model 35080B kVp Divider

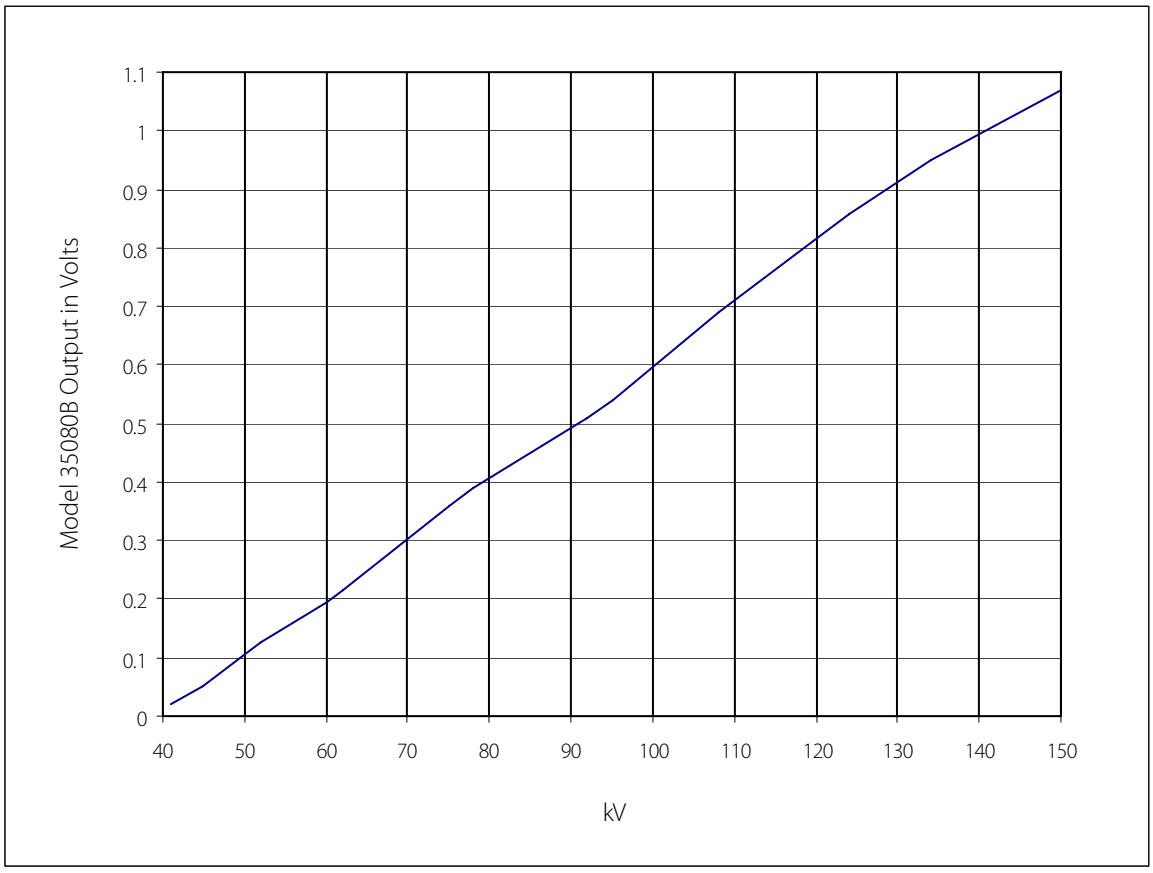

Figure 3-2 Output Ratio Plotted as a Function of kV

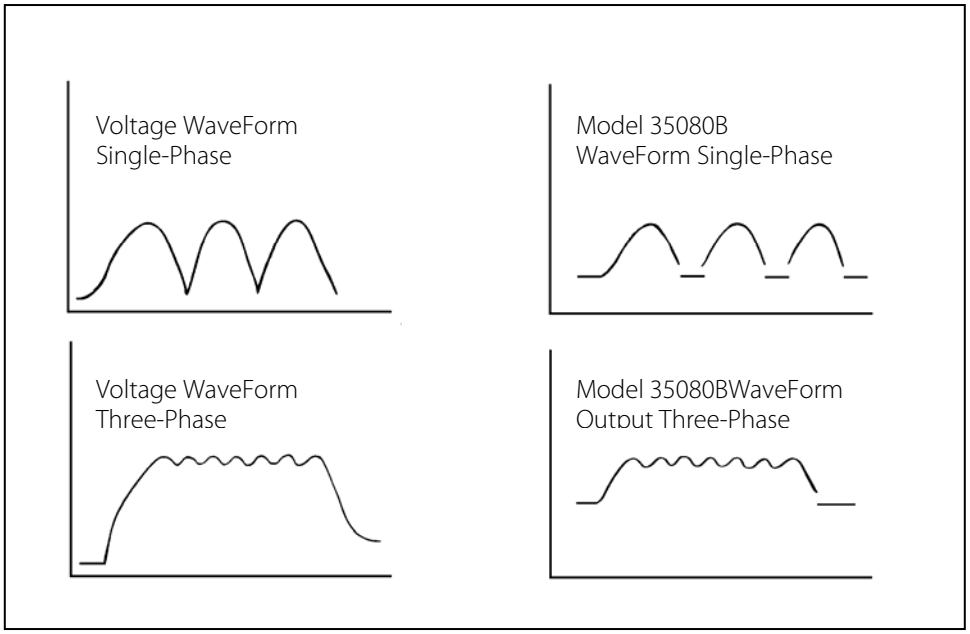

Figure 3-3. Output of the Model 35080B kVp Divider Compared to Voltage Applied to X-ray Tube

3.4 Output

In the Model 35080B kVp Divider, the intensity ratio is taken with a high-speed logarithmic ratio module. Thus, the output of the Model 35080B kVp Divider follows the kVp waveform applied to the x-ray tube within the linear range of the filter pack. The waveform differs from the waveform output of a resistive divider in that information below the kV baseline of the filter is not displayed (see Figure 3-3).

3.5 Intensity Cutoff

An examination of the Model 35080B kVp Divider waveforms in Figure 3-3 shows that as the potential of the x-ray beam waveform increases for the first time, the Model 35080B kVp Divider follows the signal as soon as it comes into the linear range of the filter pack. However, as the x-ray signal decays, the signal presented to the oscilloscope will suddenly switch to the filter pack's baseline. This effect is caused by a special circuit that prevents the presentation of a distorted signal to the oscilloscope. This circuit automatically resets about 10 seconds after an exposure is made.

3.6 Internal Calibration

In order to assure that the ratio circuit in the Model 35080B kVp Divider is stable, a "CAL" position is provided on the function switch. When the Model 35080B kVp Divider is switched into the "CAL" position, a signal ratio of 0.25 is electronically switched into the ratio circuit. This produces an output of 0.75 volts with no filter pack inserted. This value should be within ± 1% of 0.75 volts. When the Wide Range Filter Pack (37617) is inserted, a CAL voltage of 0.40 volts ± 1% is produced at the Model 35080B kVp Divider output. The CAL voltage is inscribed on each of the other filter packs. The value in kV is also given and this may be used to check the oscilloscope calibration.

NOTE

If the Model 35080B kVp Divider is exposed to an x-ray beam while the function switch is left in the "CAL" position, the resulting scope presentation will be badly distorted.

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Section 4
Test Filter Pack Option (32863)

4.1 Introduction

The Test Filter Pack (32863) provides a means for a complete system check of the Model 35080B kVp Divider's calibration. The CAL position on the kVp divider provides a check of the electronics only. The Test Filter Pack (32863) verifies the calibration of the kVp divider from radiation input through to the output signal under actual operating conditions.

4.2 SPECIFICATIONS

Output

3.00 V ± 1%

Cal

0.750 V ± 1%

X-ray Generator kV Setting

100 kV is recommended

X-ray Generator mA Setting

200 mA at 22 inches focal spot to kVp divider is recommended

4.3 Theory of Operation

Section 3 describes the theory of operation of the Model 35080B kVp divider. With the Test Filter Pack (32863) installed, the output voltage of the kVp divider is equal to three times the x-ray intensity striking the heavily filtered detector divided by the x-ray intensity striking the lightly filtered detector. The Test Filter Pack (32863) has equal thickness of copper filters for both detectors. When this filter pack is inserted into the kVp Divider, the ratio seen by the instrument (for adequately high intensities) is 1.0. The Model 35080B kVp Divider is factory-calibrated to produce 3.0 volts for a ratio of 1.0. In theory, the 3-volt value is not a function of tube current, distance or kV; in order to have a standardized test, however, the 3-volt check should be run at 22 inches focal spot to kVp divider, at 200 mA and 100 kVp. Typical waveforms from single-phase and three-phase exposures using the Test Filter Pack (32863) are shown in Figure 4-1.

4.4 Operating Instructions

The operation of the Test Filter Pack (32863) is similar to the operation of the Wide Range Filter Pack (37617) described in Section 2. Prior to taking measurements, it is suggested that the battery and internal calibration be checked as described in Sections 2.1 and 2.2. Position the kVp Divider as described in Section 2.5, Geometry of Setup.

Set up the oscilloscope to read the 3.0 volts expected from the Model 35080B kVp divider using the Test Filter Pack (32863), and make an exposure. On a properly functioning unit, the observed waveform amplitude will be 3.00 Volts ± 1%. Be aware that the oscilloscope accuracy may not be adequate for this test. The calibration of the kVp Divider can only be verified to within the accuracy of the oscilloscope or other readout device used. If the unit appears to be out of calibration, refer to Section 10.4, Calibration.

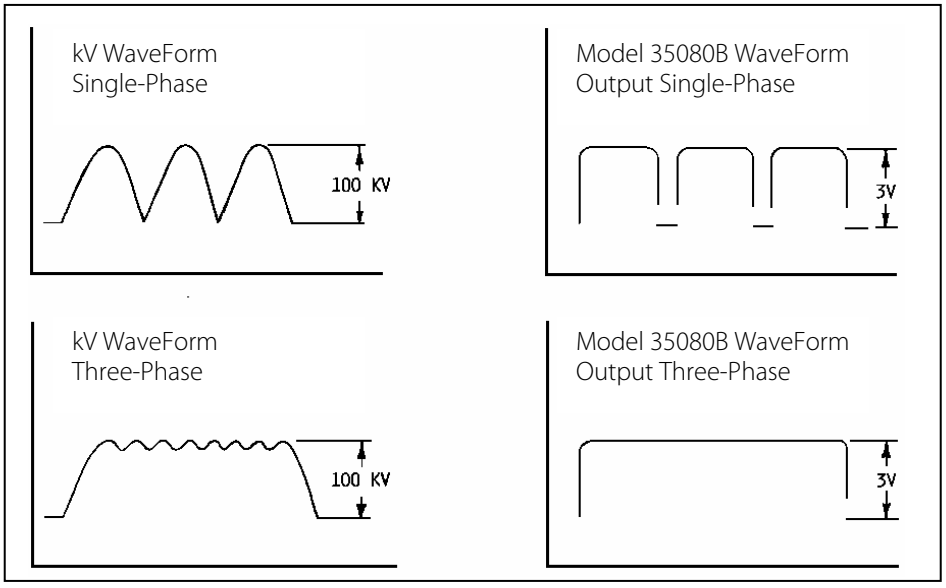

Figure 4-1. The Model 35080B kVp Divider Single-phase and Three-phase Output with the Test Filter Pack (32863)

Section 5
Cadmium K-edge Mammo Filter Pack Option (37355)

5.1 Introduction

The Cadmium K-edge Mammo Filter Pack (37355) provides a non-invasive way to make kVp measurements of mammographic x-ray generators. This filter pack uses the inherent stability of the Cadmium K-edge as an absolute reference for precision measurements between 27.5 and 29.5 kVp (for beryllium window, molybdenum anode mammographic generators with molybdenum filtration). When used in conjunction with the Linear Mammo Filter Pack (37351), precision calibrations of ± 1.0 kV accuracy can be performed from 22 to 40 kV.

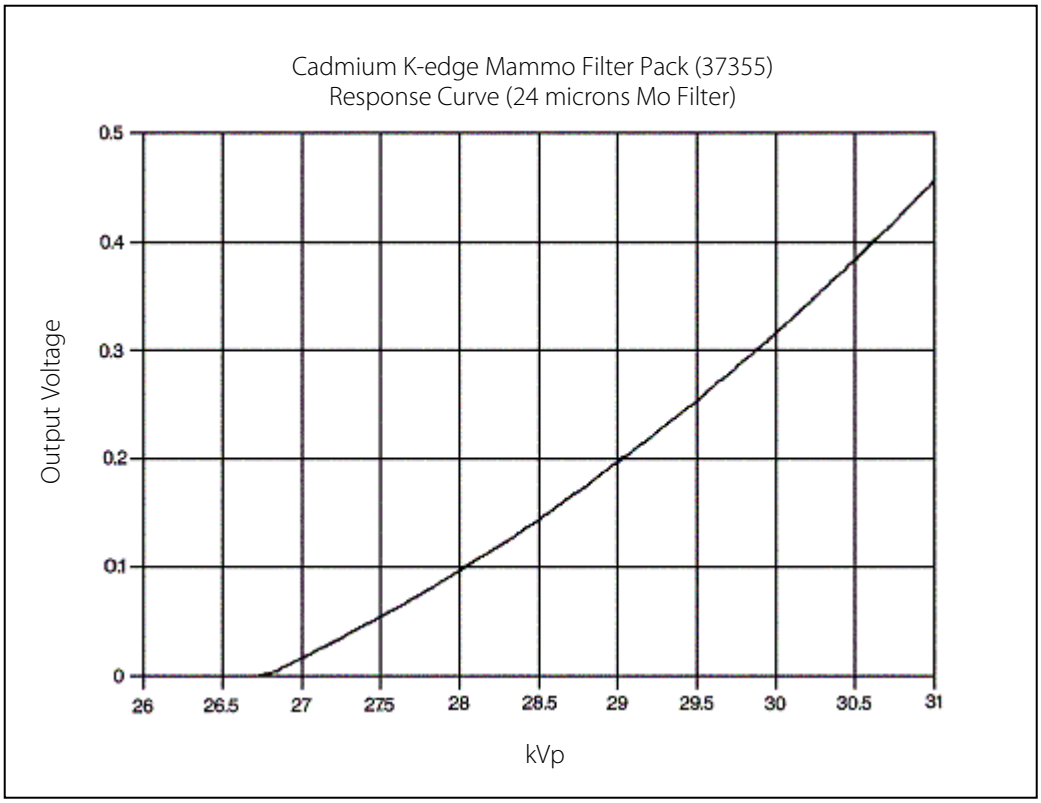

Figure 5-1. Response Curve for the Cadmium K-edge Mammo Filter Pack (37355)

5.2 Specifications

Intended Use
Beryllium window, molybdenum anode mammographic generators

Range
27.5 kVp to 29.5 kVp

Accuracy
±0.5 kV

Sensitivity
0.1 volt per kV

Zero
27.0 kV

Cal
0.75 V

Minimum Anode Current
50 mA

Target to kVp Divider Distance
12 in (30.5 cm)

Effect of Molybdenum Filtration
Negligible, 12 to 35 microns

5.3 Theory of Operation

The Cadmium K-edge Mammo Filter Pack (37355) contains two different filters side-by-side. One is constructed of cadmium, an element whose x-ray attenuation increases in a step-fashion at its K-edge (26.7 kV). The other filter is made of an element like aluminum that has no K-edge in the mammographic region. These two filters are selected to have identical attenuation characteristics for photon energies less than 26.7 kV.

The Model 35080B kVp Divider takes the ratio of the x-ray signals passing through the two filters. As long as the applied voltage to the x-ray generator is less than 26.7 kV, the output of the kVp Divider is constant (approximately 3 volts). When the applied voltage exceeds 26.7 kV, the ratio and thus the output voltage increases rapidly. The filters are carefully manufactured so that the voltage increases at 0.1 V/kV above 27.0 kV. For molybdenum anode, beryllium window generators, there is very little effect on the calibration for changes in molybdenum filtration from 12 to 35 microns. As shown by Figure 5-2, the addition of aluminum filtration does influence the sensitivity. Adding 0.25 mm of aluminum can increase the kVp divider's reading by up to 0.5 kVp.

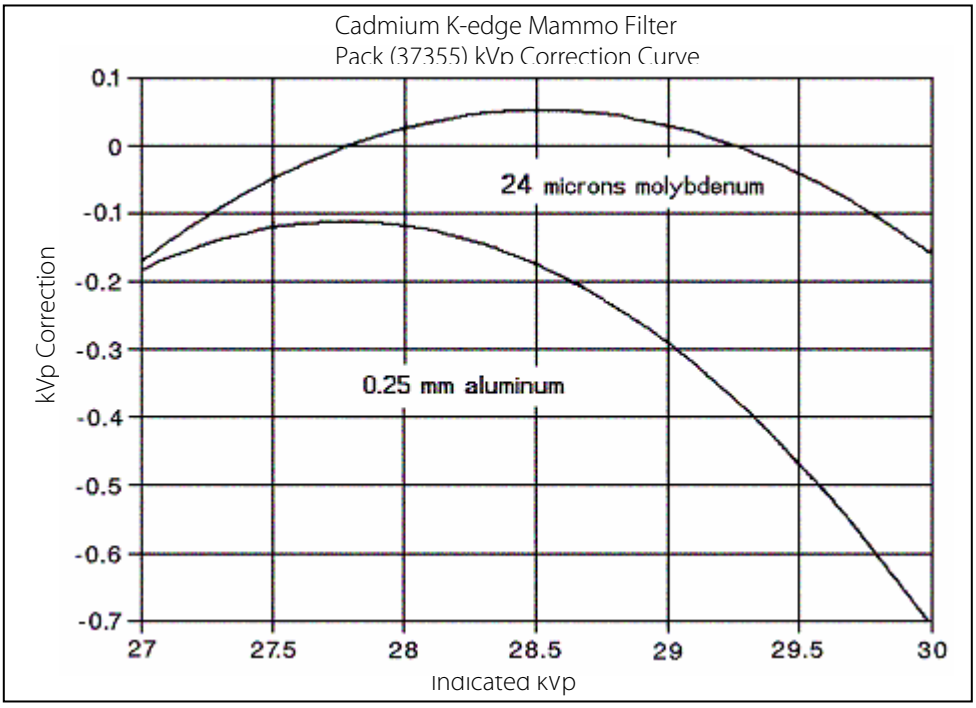

Figure 5-2. The kVp Correction Curves for the Cadmium K-edge Mammo Filter Pack (37355)

5.4 Operating Instructions

1. **Measurement Setup** - Place the Model 35080B kVp Divider in the x-ray beam on the compression paddle or other suitable support with the axis of the kVp Divider perpendicular to the axis of the x-ray tube. Raise the kVp Divider (with the Cadmium K-edge Mammo Filter Pack, 37355) as close as possible to the x-ray tube. The x-ray beam should cover the entire filter pack. (See Figure 5-3.)

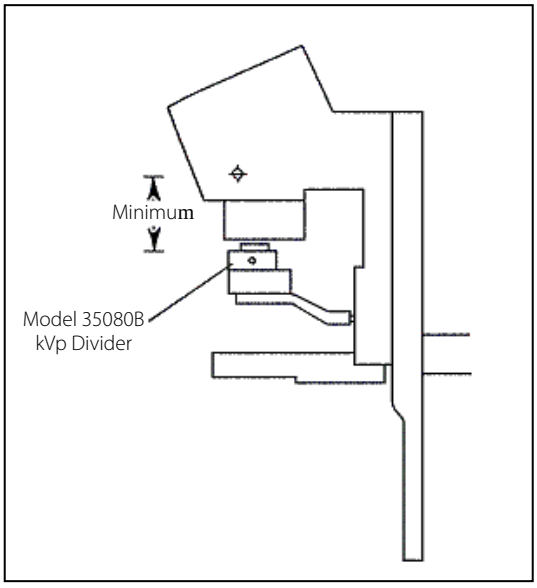

Figure 5-3. K-edge Measurement Setup

2. **Oscilloscope Setup** - Connect the kVp Divider to the scope using a shielded cable and set the vertical sensitivity set to 0.5 volts per division. With the scope input in the GROUND position, adjust the vertical position control to place the trace on the bottom graticule line. Next, set the scope in single trace, storage mode and place the input selector switch in the DC position.
3. **25 kVp Measurement Procedure** - Set the x-ray generator for 25 kVp and 100 mA. If not available, use at least 50 mA and a minimum time of 50 msec or a mAs setting that provides these tube currents. Select the Mo (molybdenum) filter and make an exposure while adjusting the scope trigger level as necessary to get a stable trace. After measuring the peak voltage, record the value.
4. **26 kVp Measurement Procedure** - Set the generator for 26 kVp and make an exposure. Record this value also. (The two voltage values should be equal to within ± 0.020 V. If so, this will be your BASE VOLTAGE; if not, then repeat steps 3 and 4 at 24 and 25 kVp respectively.)
5. **29 kVp Measurement Procedure** - Set the generator for 29 kVp and make an exposure. (If this voltage is greater than the BASE VOLTAGE by 0.1 V to 0.25 V, record this new voltage value. If this voltage is greater than the BASE VOLTAGE by higher than 0.25 V, repeat this step at one kVp lower; on the other hand, if this voltage is not greater than the BASE VOLTAGE by 0.1 V, repeat this step at one kVp higher).
6. Subtract the BASE VOLTAGE from the voltage measured in step 5. Multiply this voltage by 10 and add 27.0 to determine the true kVp for this station.
7. Proceed to Section 6.5 (Linear Mammo Filter Pack Operating Instructions).

Example 1: DC Mammographic Generator

Figures 5-4 and 5-5 show the input and output waveform obtained from exposures taken at 24, 26, and 28 kVp respectively. The baseline value of 3.10 V can be seen from the lower pair of traces on Figure 5-5. The level measured on the upper trace is 3.20 V. The kVp corresponding to this trace is calculated as:

kVp = 27.0 + [10*(3.20-3.10)] = 28.0

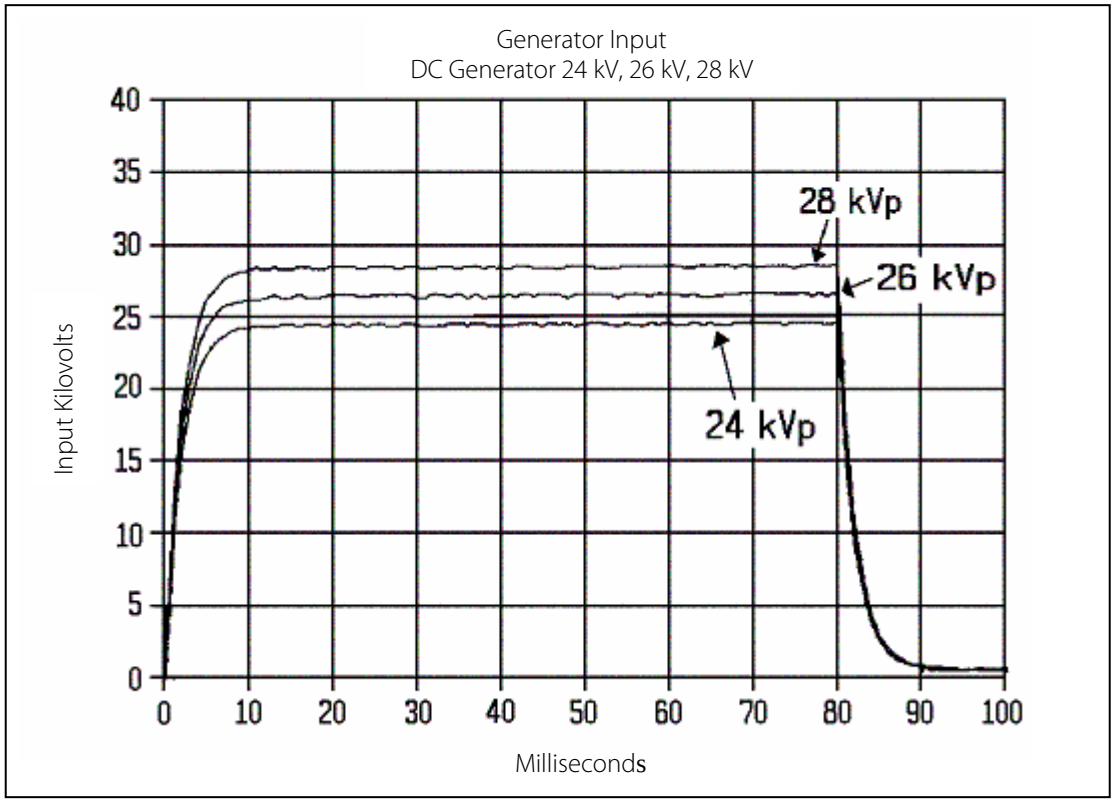

Figure 5-4. DC Mammographic Generator Input Waveforms

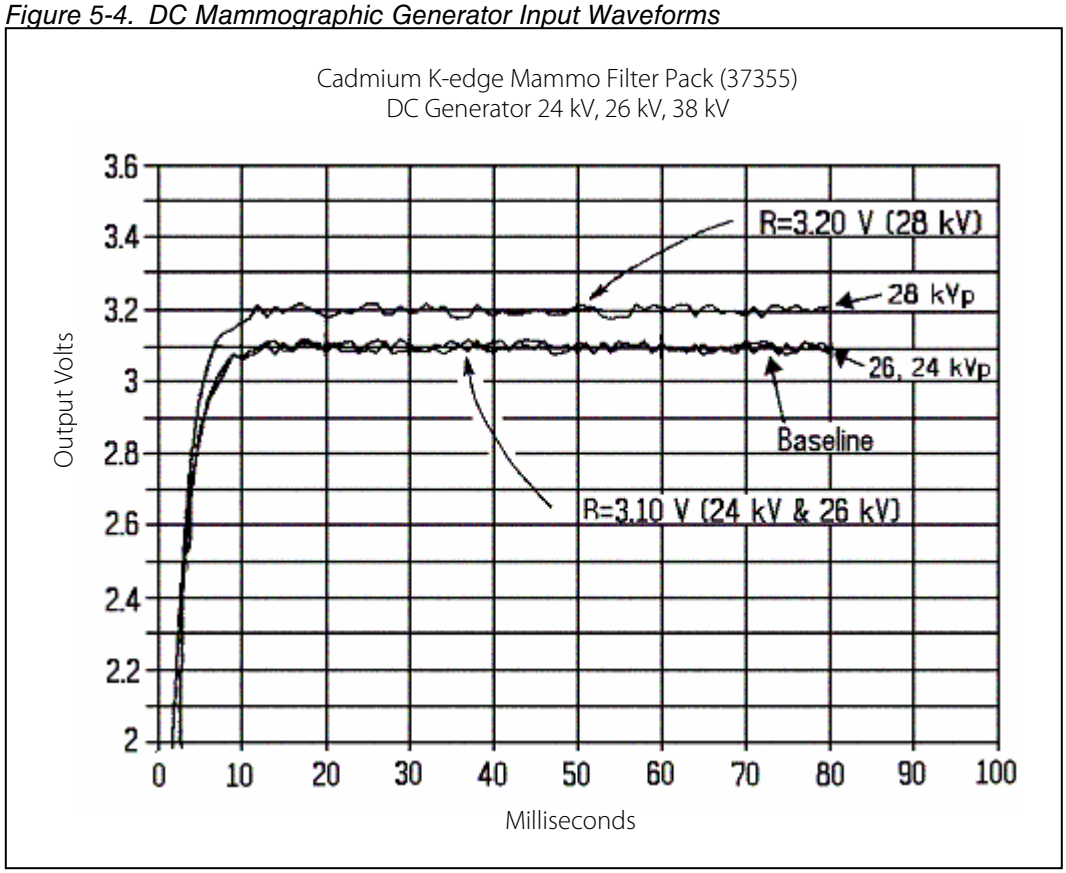

Figure 5-5. The Model 35080B kVp Divider Output Waveforms with the Cadmium K-edge Mammo Filter Pack (37355) (DC mammographic Generator)

Example 2: Single Phase Mammographic Generator

Figures 5-6 and 5-7 show the input and output waveform obtained from exposures taken at 28 kVp. Since it can be seen from Figure 6-6 that the kVp falls below the zero level of 27 kVp, the need to make several exposures while varying the kVp as in steps 3 and 4 is negated. The difference between the baseline and peak levels can be obtained from the single trace in Figure 6-7. This difference is measured to be 0.100 V, and thus the kVp is calculated as follows:

kVp = 27.0 +[10*0.100)] = 28.0.

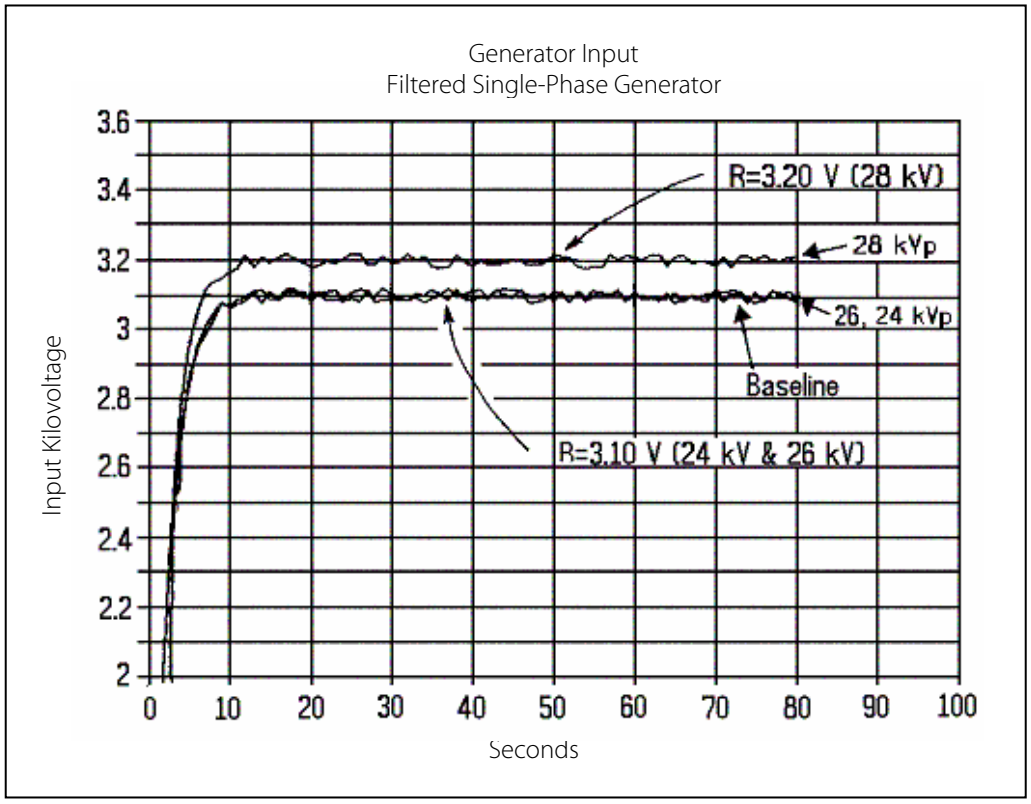

Figure 5-6. Single-phase Mammographic Generator Input Waveform

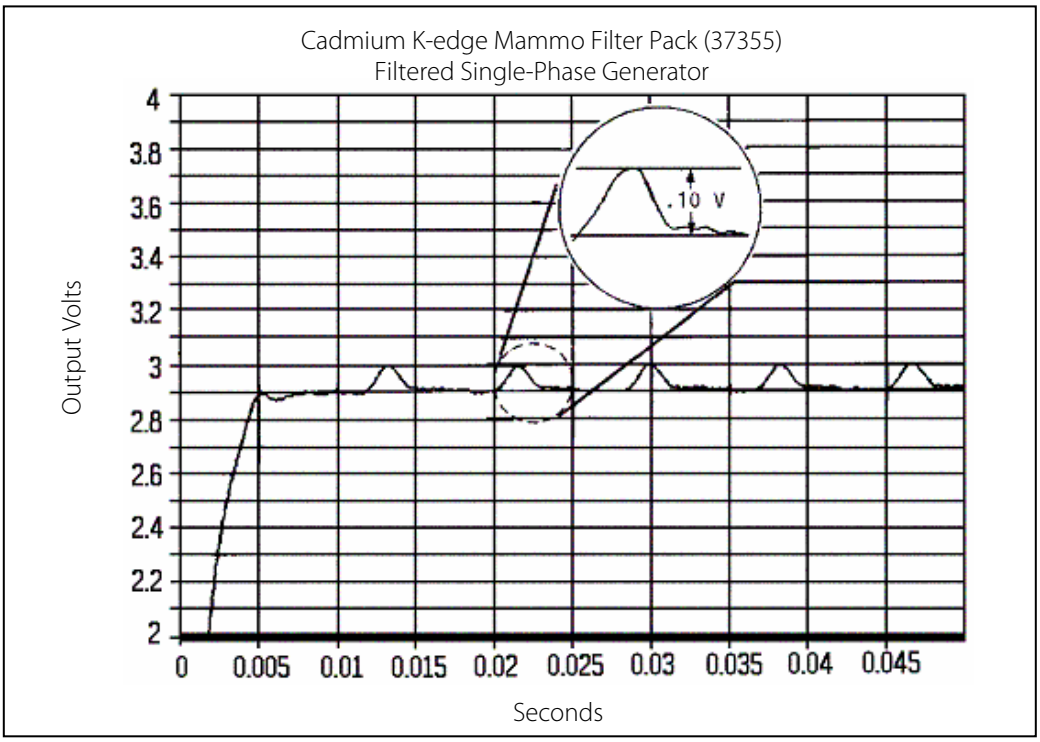

Figure 6-7. The Model 35080B kVp Divider Output Waveform with the Cadmium K-edge Mammo Filter Pack (37355) (single-phase mammographic generator)

NOTE

When proceeding to Linear Measurement, Section 6.5, Operating Instructions, do not change the generator settings.

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Section 6
Linear Mammo Filter Pack Option (37351)

6.1 Introduction

The Linear Mammo Filter Pack (37351) provides a non-invasive way to make kVp measurements of mammographic x-ray generators. This filter pack features nearly perfect linearity for precision measurements between 22 and 40 kVp (for beryllium window, molybdenum anode mammographic generators with molybdenum filtration).

6.2 Specifications

Intended Use

Beryllium window, molybdenum anode mammographic generators

Range

22.0 kVp to 40.0 kVp

Accuracy

± 1.0 kV exclusive of filtration effects

Sensitivity

0.01 volt per kV

Cal

0.200 V (20.0 kV)

Minimum Anode Current

50 mA

Target to kVp Divider Distance

12 in to 24 in (30.5 to 61 cm)

6.3 Theory of Operation

The Linear Mammo Filter Pack (37351) is similar in construction to the Wide Range linear diagnostic filter pack except that the filter elements are much thinner. As expected in mammography, measurements are more sensitive to variations in added filtration than in the diagnostic range. Thus, the Linear Mammo Filter Pack (37351) is normally used in conjunction with the K-edge Mammo Filter Pack (37355). The K-edge Mammo Filter Pack (37355) is used first to find a point between 27.5 kV and 29.5 kV very accurately. Then the Linear Mammo Filter Pack (37351) measurement is made at the same point to determine the necessary correction to apply to the Linear Mammo Filter Pack (37351) readings.

The reading from the Linear Mammo Filter Pack (37351) is compared to that taken with the Cadmium K-edge Mammo Filter Pack (37355) and a kV correction value for the Linear Mammo Filter Pack (37351) is computed. This correction value is applied uniformly to all readings taken with the Linear. The K-edge measurement should be performed each time a generator is tested. Part of the correction factor for the Linear Mammo Filter Pack (37351) is due to variations in tube filtration and part is due to positional dependence. Therefore when using the Linear Mammo Filter Pack (37351), if the Model 35080B kVp Divider is moved, a new measurement at the K-edge comparison kVp point must be made with the Linear Mammo Filter Pack (37351) and a new correction factor computed.

6.4 Corrections

If the amount of molybdenum filtration were known, the correction could be made with the correction curves in Figures 6-1 and 6-2. Figure 6-1 shows the correction required for total molybdenum filtration of 12 microns, 24 microns, and 35 microns (no correction is required for 24 microns). Figure 6-2 shows the effect of adding 0.25 mm Al to the 24 microns of molybdenum.

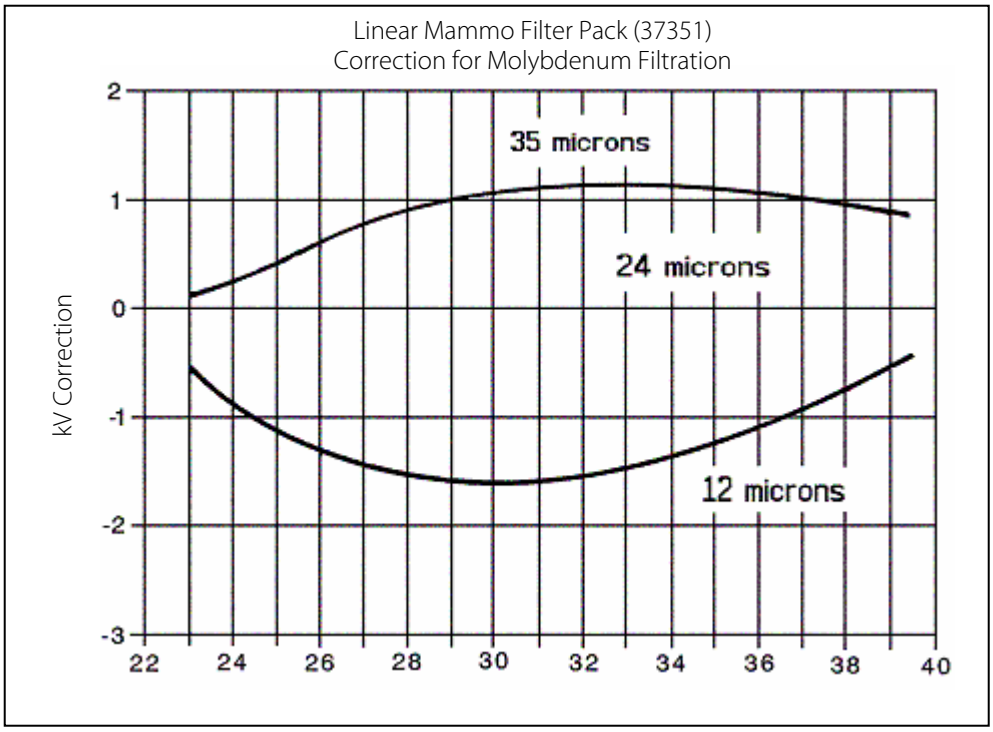

Figure 6-1. Correction Curves for 12, 24, and 35 Microns Molybdenum Filtrations

A machine with 35 microns of molybdenum and a reading of 29.0, add 1.0 kV; the corrected reading is 30.0 kVp (Refer to Figure 6-1). For 12 microns and a reading of 28.0 kVp, subtract 1.5 kV for a corrected reading of 26.5 kV.

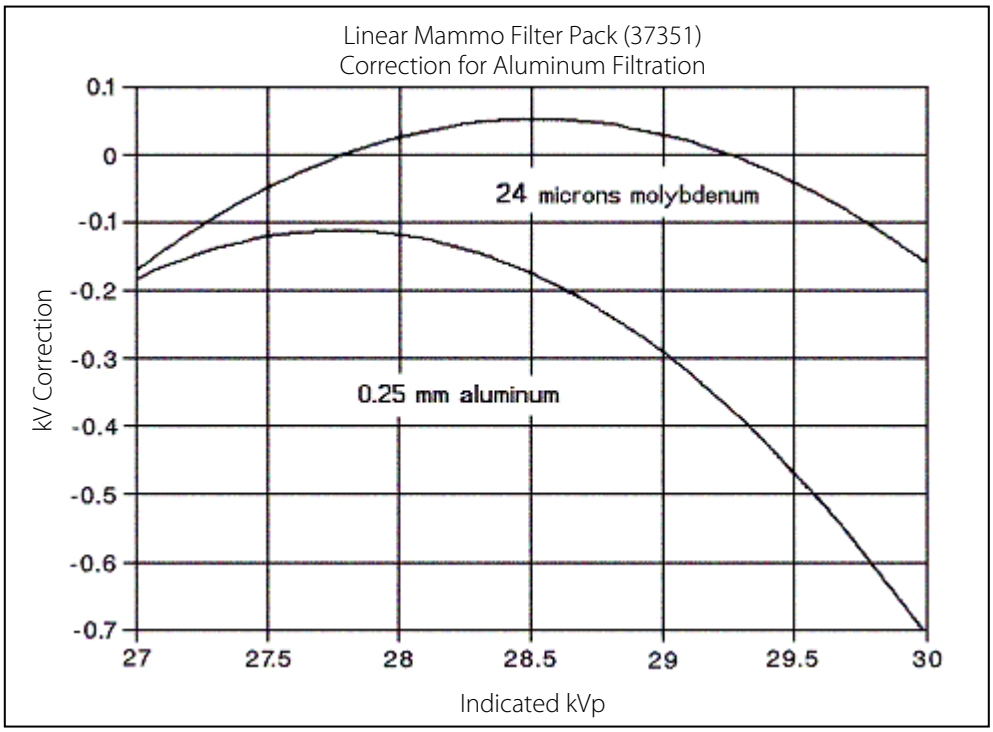

Figure 7-2. The correction curve that shows the effect of adding 0.25mm Al (0.01in Al) to the 24 microns molybdenum filter. The aluminum makes the Linear Mammo Filter Pack (37351) read high. To make corrections, subtract the kV correction from the indicated reading.

In most cases, amount of molybdenum filtration is unknown and the use of the Cadmium K-edge Mammo Filter Pack (37355) for precise calibration of the generator at a kVp between 27.5 and 29.5 kV is required.

NOTE

See Appendix A for more detailed instructions on the use of the K-edge and Linear Mammo Filter Packs (37355 and 37351 respectively).

6.5 Operating Instructions

This procedure will normally follow that given in Section 5.4 where measurement with the Cadmium K-edge Mammo Filter Pack (37355) ended.

1. Measurement Setup **-** Replace the Cadmium K-edge Mammo Filter Pack (37355) with the Linear Mammo Filter Pack (37351). Reposition the Model 35080B kVp Divider to approximately 15 inches from the focal spot by lowering the compression paddle or other support device (see Figure 6-3).

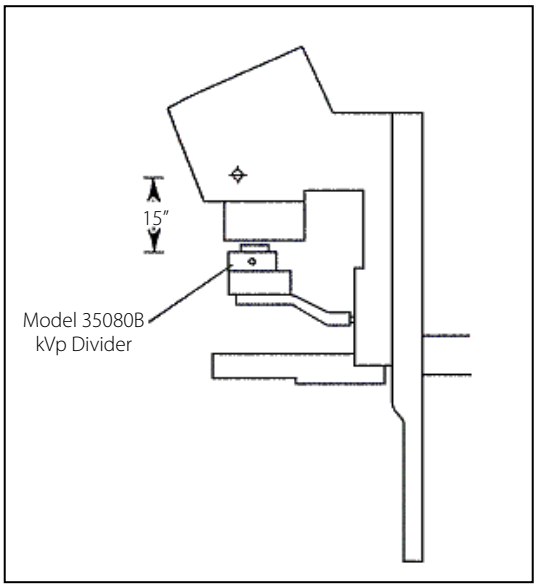

Figure 6-3. Linear Measurement Setup

2. Connect the kVp Divider output to either a storage oscilloscope or a peak-read-and-hold DMM. Set the oscilloscope to 0.05 volts division vertical gain and the input to DC Coupled, single trace storage mode.

NOTE

The Linear Mammo Filter Pack (37351) may be used with a peak-read-and-hold DMM for the readout instead of or along side of the storage oscilloscope. The device is direct-reading in kVp. Merely multiply the display reading by 100. For example, a voltage of 0.375 is equivalent to 37.5 kV.

3. With the Linear Mammo Filter Pack (37351) installed on the kVp Divider, move the switch to the ‘‘CAL’’ position. The voltage output should be 0.200 volts ±.003 volts (1% + 1 digit). Check CAL voltage with a digital voltmeter or an oscilloscope with at least 0.1% accuracy. This value corresponds to a kV reading of 20.0 kV and may be used to setup the oscilloscope. The CAL function checks the gain of the kVp Divider. A 1% error in gain will result in a 1% error in the kVp reading (0.3 kV at 30 kV).
4. With the same generator settings used for K-edge measurement at 29 kVp (see Section 5.4), turn the kVp Divider to ‘‘OFF’’ and position the oscilloscope trace on the bottom line. Place the kVp Divider in the ‘‘CAL’’ position, and the trace will move to the middle line (20 kV). The oscilloscope with eight major vertical positions is now set to indicate a range of 0 to 40 kV. Make an exposure and record this value separate from the K-edge reading made in Section 5.4, step 6.

NOTE

The CORRECTION VALUE may be either negative or positive.

5. Measure other kVp values as desired. Record the LINEAR VOLTAGE, multiply by 100 and this will be your uncorrected LINEAR KVP. Lastly, add or subtract the CORRECTION VALUE and record the results. This now has the true kVp value for all kVp's measured.

NOTE

See Appendix A for step-by-step instructions on using the Linear Mammo Filter Pack (37351) in conjunction with the Cadmium K-edge Mammo Filter Pack (37355).

6. Subtract this kVp voltage from the true K-edge kVp value (see Section 5.4). (This will be the CORRECTION VALUE applied to all kVp measurements made with the Linear Mammo Filter Pack, 37351.)

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Section 7
CT Filter Pack Option (33551)

7.1 Introduction

The CT Filter Pack (33551) provides a non-invasive way to make independent tests of the internal voltage divider of a CT system -- and a convenient and safe way to check tube voltage.

The actual kV waveform of the CT machine can be displayed on a storage oscilloscope. If the CT machine is a DC (continuous scan) unit, the proportional voltage can be read on a DMM.

These applications are made possible with the CT Filter Pack (33551) in conjunction with the Model 35080B kVp Divider.

7.2 Specifications

Range

70 to 140 kV

Sensitivity

0.1 V/10 kV

Cal

0.644 V

Zero

60 kV

Cal

124.4 kV

Linearity

Less than 1 kV correction from 70 to 140 kV

Calibration Filtration

2.5 mm Al

Filtration Effect

Less than 1 kV per mm Al difference in filtration (from the 2.5 mm Al calibration standard) over the 70 to 140 kV range

Active Area

40 mm x 6.5 mm

Minimum Anode Current

25 mA at 25 inches

7.3 Theory of Operation

The Model 35080B kVp Divider contains a pair of solid-state detectors which when exposed to x-rays, send signals to a ratio module. The resulting ratio depends on the kV of the CT beam and the difference in thickness of filters placed between the detectors and the beam source.

The filters are carefully selected to give the best response curve possible over the kV range of CT interest (see Specifications).

The narrow dimensions of the CT Filter Pack's (33551) detector area are suited to the beam area restrictions of CT applications.

7.4 Operating Instructions

1. Select 2.5 mm Al filtration and remove beam-restricting devices from the CT beam path on the CT machine. Open the beam width to 10 mm to cover the sensor area on the CT Filter Pack (33551). Use the patient-positioning laser to align the Model 35080B kVp Divider within the beam.
2. Connect the kVp Divider output to a storage oscilloscope.
3. Set the oscilloscope sensitivity to 0.1 V/div, DC Coupled.
4. Put the kVp Divider into the ‘‘CAL’’ mode and verify its output is 0.644 volt ± 1%.
5. Turn the kVp Divider OFF and position the oscilloscope trace to read 60 kV (the reference baseline on the oscilloscope which is added to the measured value).
6. Again, put the kVp Divider into the ‘‘CAL’’ mode and verify that the oscilloscope trace corresponds to 124.4 kV (± 1 kV).
7. Place the tube head in its top position.
8. Switch the kVp Divider into the ‘‘RUN’’ mode and make the exposure.

7.5 Correction of Readings

Filtration

No correction is needed for 2.5 mm Al (Refer to Figure 7-1.) . For a given kV reading: if the effective filtration of the CT beam is greater than 2.5 mm Al, subtract the difference (in mm) times the correction factor from the apparent reading; if the effective filtration is less than 2.5 mm Al, add the difference times the correction factor to the apparent reading.

Example 1

The kV reading is 100, and the total filtration of the beam is 3.5 mm Al. The difference between the effective and calibration filtration is 1 mm. This difference times the correction factor for 100 kV is 1 x 0.35 = 0.35 kV. Therefore the corrected kVp is calculated as 100kV - 0.35 kV = 99.65 kV.

Example 2

The kV reading is 80, and the total filtration is 2.0 mm Al. The difference between the effective and calibration filtration is 0.5 mm. The difference times the correction factor for 80 kV is 0.5 x 0.2 = 0.10 kV. Therefore, 80 kV is 0.5 x 0.2 = 0.10 kV. Therefore, 80 kV + 0.10 kV = 80.1 kV.

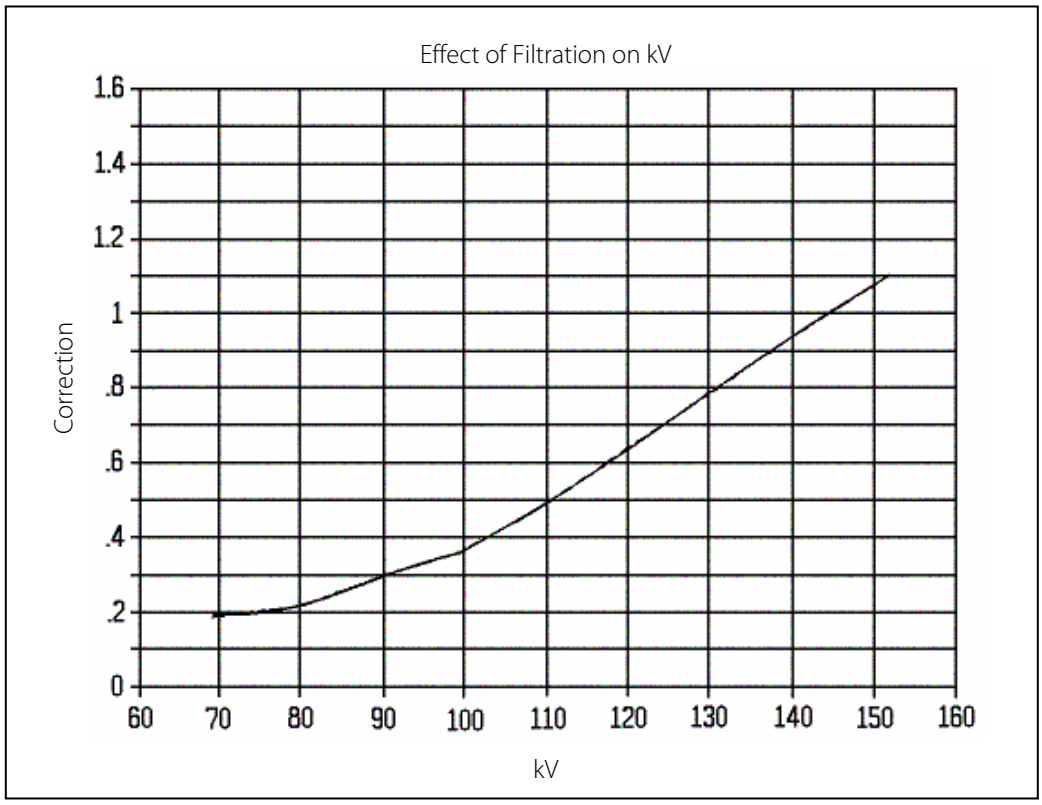

Figure 7-1. CT Filter Pack (33551) Filtration Effect Correction Curve

Linearity

(Refer to Figure 7-2.) If a kV correction value (from the Y-axis) has a negative sign, then its magnitude is subtracted from the apparent reading shown on the X-axis. If a kV correction value is positive, then its magnitude is added to the apparent kV reading on the X-axis.

Example 1

If the apparent reading is 70 kV, the correction value is -1. Since the correction value has a negative sign, it is subtracted from the apparent reading. Therefore, 70 kV - 1 kV = 69 kV.

Example 2

If the apparent reading is 80 kV, the correction value is 0.9. Since the correction value has a positive sign, it is added to the apparent reading. Therefore, 80 kV + 0.9 kV = 80.9 kV.

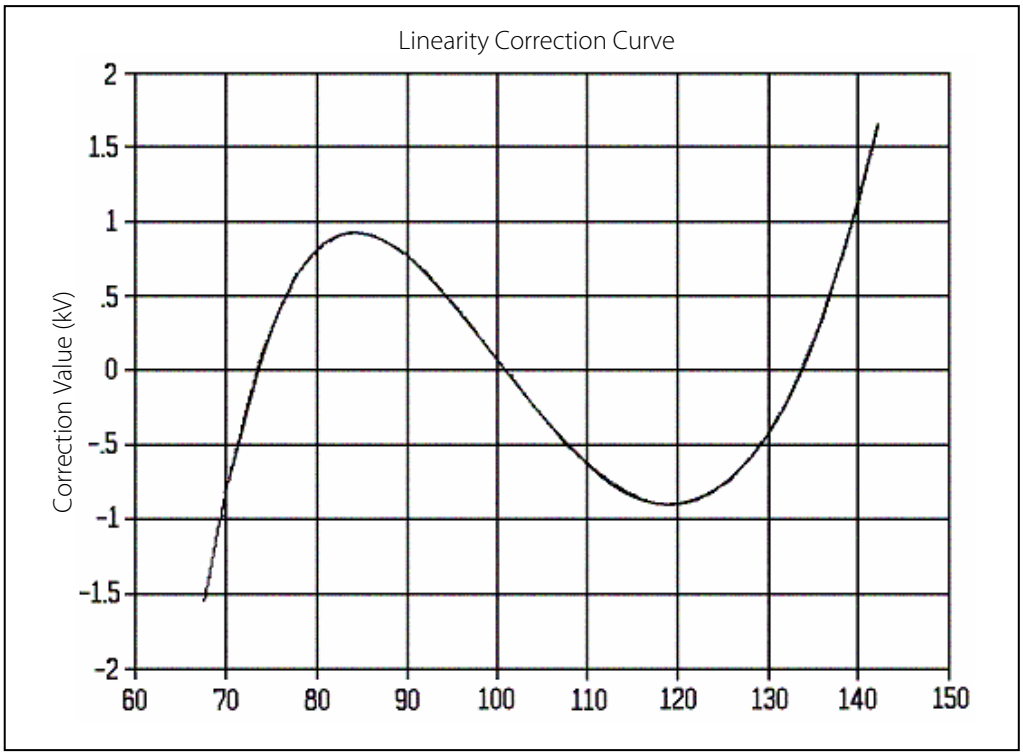

Figure 7-2. CT Filter Pack (33551) Linearity Correction Curve

Section 8
Mobile Filter Pack Plus Option (37946)

8.1 Introduction

The Mobile Filter Pack Plus (37946) is a specialized filter pack designed primarily for use on mid- to high-frequency generators (1 kHz) with substantial kV ripple (10%). For single-phase and 3-phase generators, or other low-frequency generators (< 1 kHz), use of the Mobile Filter Pack Plus (37946) is not recommended. The Wide Range Filter Pack (37617) should be used for these applications. Measurements below the 50kV operating range of either the Mobile Filter Pack Plus (37946) or the Wide Range Filter Pack (37617) should be made with the Low Range Filter Pack (38237).

When an invasive kV divider is connected to high frequency, high-ripple generators for calibration, the kV waveform is often substantially changed due to the capacitance of the added high voltage cables. When the invasive divider is subsequently removed for normal operation of the x-ray system, the kVp at any given generator setting may be significantly higher than was measured with an invasive divider. The Model 35080B kVp Divider with the Mobile Filter Pack Plus (37946) provides an easy and accurate non-invasive method for measuring the kVp of these systems.

The operating instructions for the Mobile Filter Pack Plus (37946) are the same as given in Section 4 for the Wide Range Filter Pack (37617) with minor exceptions as detailed below. The recommended focal spot to kVp divider distance is 12 inches, rather than the 22 inches suggested for the Wide Range Filter Pack (37617). The long axis of the Model 35080B kVp Divider should still be perpendicular to the x-ray tube axis to avoid “heel effect”, as shown in Figures 2-2 and 2-3.

The formula used to calculate the kV is the same as for the Wide Range pack:

kV = Model 35080B voltage x 100 + ZERO kV

where the ZERO kV is 40 for both the Mobile and Wide Range Filter Packs (37946C and 37167). However, when the kVp divider is placed in the “CAL” mode with a Mobile Filter Pack Plus (37946) inserted, an output voltage of 0.600 V ± 1% should be obtained, corresponding to a CAL kV of 100.

The kVp Divider has a special circuit intended to prevent the presentation of a distorted waveform at low intensities. Section 3.5, Intensity Cutoff, discusses the effect of this circuit for single-phase waveforms. For generators with substantial kV ripple, for which the Mobile Filter Pack Plus (37946) is intended, this same effect may be noticed. As the kV waveform decreases, the output suddenly switches to the filter pack’s baseline, which corresponds to 40 kVp with the Mobile Filter Pack Plus (37946). During the rising portion of the next kV cycle, the output will switch back to and follow the actual waveform, as shown in Figure 3-3 for the single-phase example. This is normal operation of the Model 35080B kVp Divider for large ripple signals.

The filtration and linearity correction curves for the Mobile Filter Pack Plus (37946) are given in the next two sections. Two linearity curves are shown. The solid line on the linearity graph is the standard linearity curve for an x-ray generator with a 2 kHz waveform with 20% observed ripple. The dashed line is normally not used, but shows the linearity curve for generators with DC to 720 Hz ripple components.

8.2 Specifications

Range

50 to 135 kV

Sensitivity

0.1 V/10 kV

Cal

0.600 V

Zero

40 kV

Cal

100 kV

Calibration Filtration

2.5 mm Al

8.3 Filtration Effect Corrections

Corrections for filtration are made using the correction curve shown in Figure 8-1. The Mobile Filter Pack Plus (37946) is calibrated at 2.5 mm Al total filtration, so measurements made at other filtration values require correction of the measured reading. Corrections are made by subtracting the total filtration of the x-ray machine being measured from 2.5 mm Al, multiplying the result by the value read off the chart for the measured kVp, and adding this result to the measured kVp.

Example

The Model 35080B kVp Divider with a Mobile Filter Pack Plus (37946) inserted reads 80kVp. The x-ray system has 3.3 mm Al total filtration. The filtration effect curve of Figure 8-1 indicates a filtration effect of 1.05 kVp per mm Al at 80 kVp. The difference in filtration, 2.5 - 3.3 = -0.8 mm Al, is multiplied by the correction value to yield -0.8 x 1.05 = -0.84 kVp. This number is then added to the apparent reading to obtain the actual kVp, which is 80 kVp + (-0.84 kVp) = 79.16 kVp.

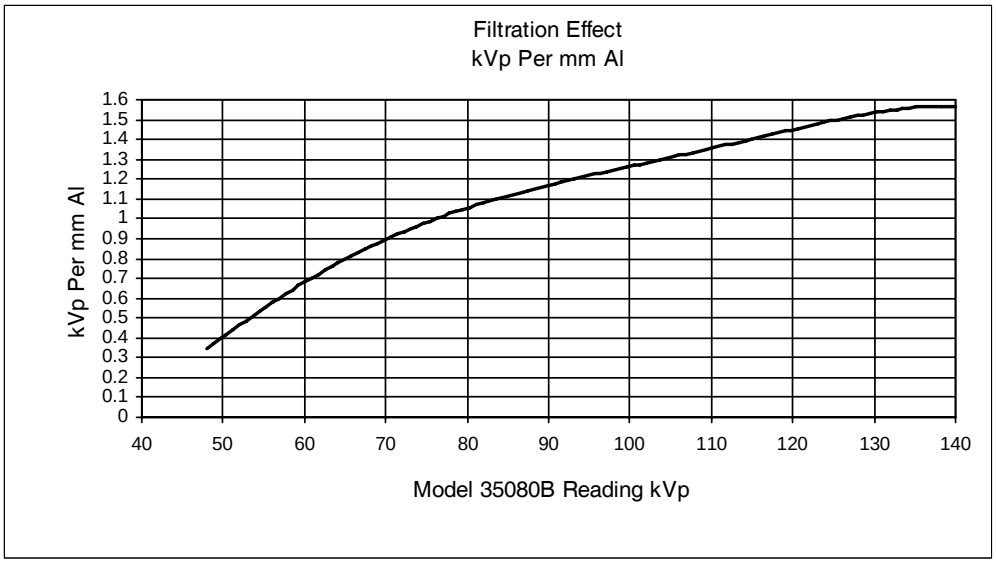

Figure 8-1. Mobile Filter Pack Plus (37946) Filtration Effect Correction Curve

8.4 Linearity Corrections

Corrections for linearity of the Mobile Filter Pack Plus (37946) can be made by taking the measured output of the Model 35080B kVp Divider and adding the value in kVp shown on the curve in Figure 8-2. The curve shown by the solid line in Figure 8-2 is normally used for x-ray generators with an observed ripple amplitude and frequency of approximately 20% at 2 kHz. For best accuracy, filtration corrections should be made prior to the linearity corrections. However, if the difference in total filtration from the calibration standard of 2.5 mm Al is small, linearity corrections alone may be sufficient. See Section 9.3 for information regarding filtration corrections.

Example

The Model 35080B kVp Divider with a Mobile Filter Pack Plus (37946) has a reading of 83 kVp. From the chart, a kVp Correction value of -0.9 kVp is obtained. Assuming filtration corrections are not required for this x-ray system, the actual kVp is 83 + (-0.9) = 82.1 kVp.

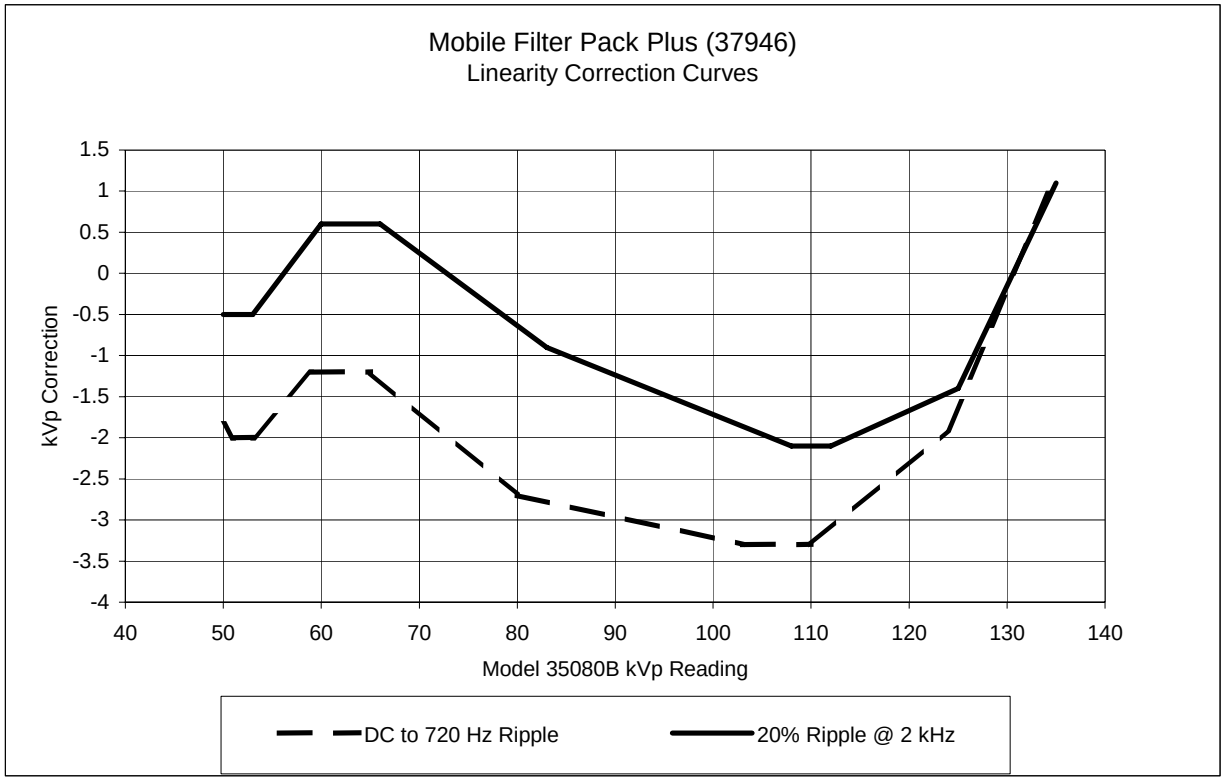

Figure 8-2. Mobile Filter Pack Plus (37946) Linearity Correction Curve. The kVp Correction Value read from the vertical scale should be added to the Model 35080B kVp Divider reading to obtain the corrected kVp result.

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Section 9
Low Range Filter Pack Option (38237)

9.1 Introduction

The Low Range Filter Pack (38237) is optimized for measurements in the 30-kVp to 90-kVp range. It can be used to make measurements below the 50-kVp lower limit of the Wide Range Filter Pack (37617) and Mobile Filter Pack Plus (37946) on x-ray generators with settings below 50 kVp. The Low Range Filter Pack (38237) will typically operate at lower mA settings, making it useful in taking measurements difficult to obtain with either the Wide Range Filter Pack (37617) or Mobile Filter Pack Plus (38237) at the lower end of their kVp operating range.

9.2 Specifications

Range

30 kVp to 90 kVp

Sensitivity

0.1 V/10 kV

Cal

0.150 V

Zero

26 kV

Cal

41 kV

Accuracy

± 2%, exclusive of linearity and filtration effects

Minimum Anode Current for less than ± 1 kV effect

Typical at 22 inches with a 3 phase x-ray generator, 3 mA from 90 kVp down to 50 kVp, increasing to 10 mA @ 40 kVp and 30 mA @ 30 kVp.

9.3 Theory of Operation

The Low Range Filter Pack (38237) operates in a manner similar to the operation of the Wide Range Filter Pack (37617) described in Section 3. The thickness and composition of the filters have been optimized for operation over the 30 kVp to 90-kVp range in the Low Range Filter Pack (38237). The filter differences cause the different Cal and Zero voltages specified, and require different correction curves shown later in this section.

9.4 Operating Instructions

The operation of the Low Range Filter Pack (38237) is similar to the operation of the Wide Range Filter Pack (37617) described in Section 2. Prior to taking measurements, it is suggested that the battery and internal calibration be checked as described in Section 2.1 and 2.2.

OSCILLOSCOPE SETUP

Two possible methods for reading the output of the Model 35080B kVp Divider on a storage oscilloscope are to read the kVp divider output voltage and then convert the voltage into the equivalent kV using the conversion formula, or to set up the oscilloscope to allow direct readout of kV. Both methods are described and assume that the operator is familiar with the use of his storage oscilloscope.

Converting voltage reading into kV

The following formula is used to convert a voltage reading obtained from the Model 35080B kVp Divider into the equivalent kV:

kV = (kVp Divider Voltage) x 100 + ZERO kV

Example

The peak voltage located on the waveform captured by the storage oscilloscope is 0.280 volts. The ZERO kV of the Low Range Filter Pack (38237) is 26 kV. This reading represents a kVp of:

kV = 0.280 x 100 + 26

kV = 28 + 26

kV = 54 kV

Setup for direct kV readout

1. Insert the Low Range Filter Pack (38237) into the Model 35080B kVp Divider and connect the kVp divider output to the oscilloscope input using a BNC to BNC coaxial cable.
2. Set the oscilloscope gain to 0.1 V/div, DC Coupled. This corresponds to a 10-kV/div. sensitivity.
3. Set the FUNCTION switch of the kVp divider to the CAL position. The kVp divider will provide a voltage that represents 41 kV. Adjust the oscilloscope vertical position control to place the trace 0.9 division below the center of the screen.
4. Set the FUNCTION switch of the kVp divider to the RUN position. The oscilloscope trace will move down to approximately 2.4 divisions below the center of the screen. Do not readjust the trace positioning any further.
5. The center line on the oscilloscope screen is now adjusted to represent 50 kV. Each division represents a 10kV increment. One division above the center line is 60 kV, two divisions above is 70 kV, and so forth. Similarly, one division below the center line is 40 kV, and two divisions below is 30 kV.

GEOMETRY OF SETUP

The Model 35080B kVp Divider with the Low Range Filter Pack (38237) is set up for use in the same manner as described in Section 2.5 for the Wide Range Filter Pack (37617).

The normal setup described in Section 2.5 calls for 200 mA and 22 inches. Lower current settings may be used in many cases; however, the detectors in the kVp divider require a minimum intensity below which the output voltage of the kVp Divider develops noise and errors. The minimum mA at a given distance varies from generator to generator. The typical specification is given for guidance only. If a particular test setup seems to be giving noisy or erroneous readings, increase the mA setting of the generator, reduce the distance from the source to the kVp divider, or both. When reducing the distance from the focal spot to the kVp divider, make sure that the x-ray beam is wide enough to cover the active area of the filter pack at the distance used.

9.5 Filtration Effect Correction

The Low Range Filter Pack (38237) is calibrated at 2.5 mm Al total filtration. Measurements made at other filtration values require a correction to the measured reading. Corrections for filtration are made using the correction curve shown in Figure 9-1. Corrections are made by subtracting the total filtration of the x-ray machine being measured from 2.5 mm Al, multiplying the result by the value read off the chart for the measured kVp, and adding this result to the measured kVp.

Example

A reading of 49 kVp is obtained from a Model 35080B kVp Divider using a Low Range Filter Pack (38237). The x-ray system has 3.3 mm Al total filtration. The filtration effect curve of Figure 9-1 indicates a filtration effect of 0.5 kVp per mm Al at 49 kVp. The difference in filtration, 2.5 - 3.3 = -0.8 mm Al, is multiplied by the correction value to yield -0.8 x 0.5 = -0.4 kVp. This number is then added to the apparent reading to obtain the actual kVp, which is 49 kVp + (-0.4 kVp) = 48.6 kVp.

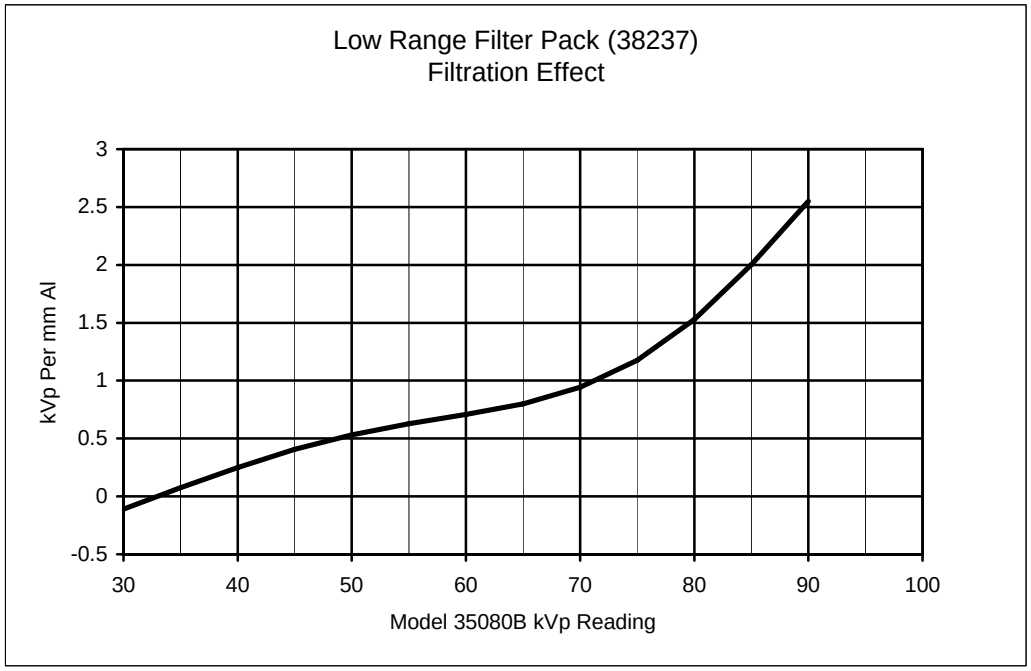

Figure 9-1. Low Range Filter Pack (38237) Filtration Effect Correction Curve

9.6 Linearity Correction

Corrections for the linearity of the Low Range Filter Pack (38237) can be made by taking the measured output of the Model 35080B kVp Divider and adding the value in kVp shown on the curve in Figure 9-2. For best accuracy, a filtration correction should be made prior to the linearity correction. If the difference in total filtration from the calibration standard of 2.5 mm Al is small, however, linearity corrections alone may be sufficient.

Example

The Model 35080B kVp Divider with a Low Range Filter Pack (38237) has a reading of 45 kVp. From the chart, a kVp Correction value of -0.2 kVp is obtained. Assuming filtration corrections are not required for this x-ray system, the actual kVp is 45 + (-0.2) = 44.8 kVp.

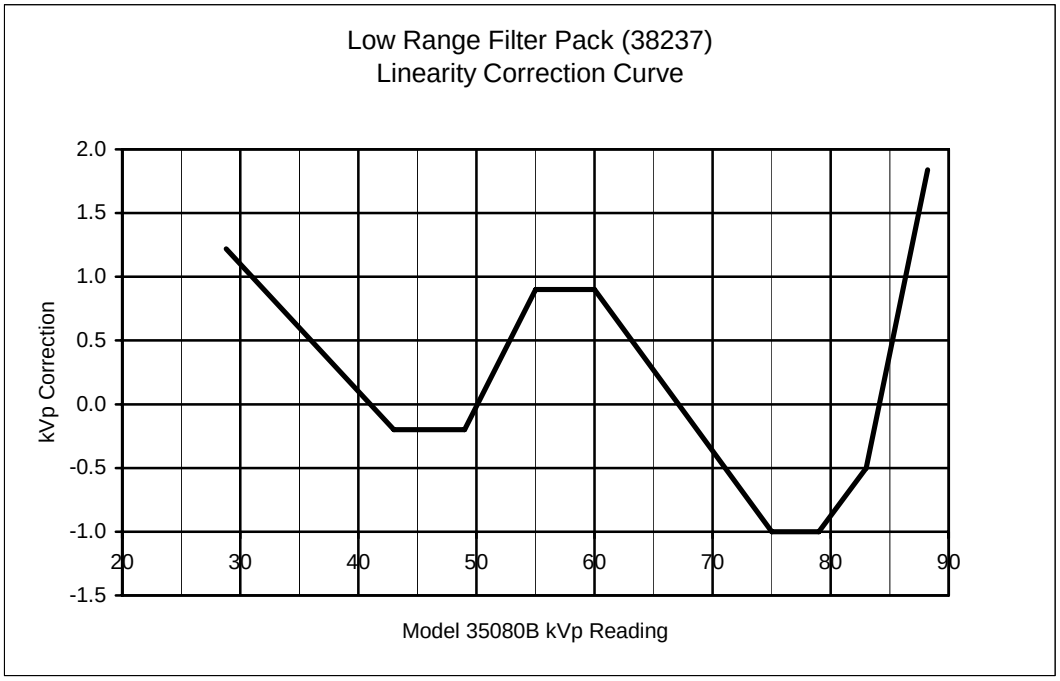

Figure 9-2. Low Range Filter Pack (38237) Linearity Correction Curve. The kVp Correction Value read from the vertical scale should be added to the Model 35080B Model 35080B kVp Divider reading to obtain the corrected kVp result.

Section 10
Maintenance

10.1 Cleaning the Instrument

To clean the exterior of the instrument, follow these steps:

1. Turn off the instrument and disconnect the output connector.
2. Moisten a soft cleaning cloth with a solution of three parts water and one part liquid dishwashing detergent.

   Do not soak the cloth in the solution; you must not let the solution drip inside the instrument.
3. Use the moistened cloth to wipe the instrument's exterior cover.
4. Let the instrument dry completely before using.

10.2 Troubleshooting

Difficulties experienced by the Model 35080B kVp Divider user may be caused by problems from one or more of the three sources described below: problems with the storage oscilloscope used to obtain the kV reading; problems with the x-ray machine; and either improper technique or an electronic fault with the kVp divider. Typically, the existence of a problem would be signaled by one of the following:

1. No waveform on the oscilloscope trace;
2. A strange or unexpected waveform on the oscilloscope trace.

The information given below is provided to direct the user to the most likely sources of minor problems; it is not meant to provide all solutions to all possible problems.

PROBLEMS WITH THE OSCILLOSCOPE

1. If the oscilloscope settings for CAL and ZERO are not correct, a waveform may not be displayed, or an unusual or unexpected waveform may be observed (refer to Section 4.4).
2. The oscilloscope may be grounded or inoperative.

   Check the operation of the oscilloscope.
3. The oscilloscope trigger may be set improperly.

PROBLEMS WITH THE X-RAY MACHINE

1. The x-ray machine may be inoperative.

   Verify with a dosimeter that the x-ray machine is functioning.
2. The x-ray machine may be arcing. Arcing is characterized by erratic spikes superimposed on the kV waveform.
3. The x-ray machine may be badly adjusted.

PROBLEMS WITH THE MODEL 35080B KVP DIVIDER

1. The power battery may be weak or dead.

   Check the battery and replace it if necessary (see Section 2.1, Battery Check, and Section 10.3, Battery Replacement).
2. The function switch on the Model 35080B kVp Divider may be in the wrong position, such as “CAL”.

   Verify that the function switch is in the “RUN” position.
3. Orientation of the kVp divider may not be correct for the location of the x-ray source.

   (Refer to Section 2.5, Geometry of Setup.) Turn the kVp divider upside-down for under-table x-ray heads and right side up for above-table x-ray heads.
4. There may be an electronic fault in the kVp divider.

   Check the CAL operation of the kVp divider (refer to Section 2.2, Internal Calibration Check).

10.3 Battery Replacement

The Model 35080B kVp Divider is powered by a single 9 V Eveready type 522 alkaline battery. Battery life is approximately 60 hours. The battery condition can be checked without opening the instrument case; with the function switch in the “BAT CHK” position, a digital voltmeter (DVM) can be connected to the output connector.

NOTE

Do not leave the function switch in the “BAT CHK” position, as this will decrease battery life.

If the battery voltage drops below 7.0 V, the battery should be replaced, as the remaining life of the battery is quite limited. If the battery voltage is already below 6.5 volts when checked, the battery must be replaced for proper operation of the kVp divider.

To replace the battery, remove the screw from the cover on the bottom of the kVp divider (refer to Figure 10-1). Lift the cover from the instrument case. Place your hand over the battery compartment and roll the instrument upright, letting the battery drop into your hand.

Carefully disconnect the battery terminal from the used battery and replace it with a fresh 9 V alkaline battery (Eveready type 522). Slip the battery back into the compartment and replace the cover. Note that the leading edge of the cover must be inserted under the lip of the instrument case before it is properly seated (refer to Figure 10-1). Align the hole in the cover with the threaded hole in the case and reinsert the screw.

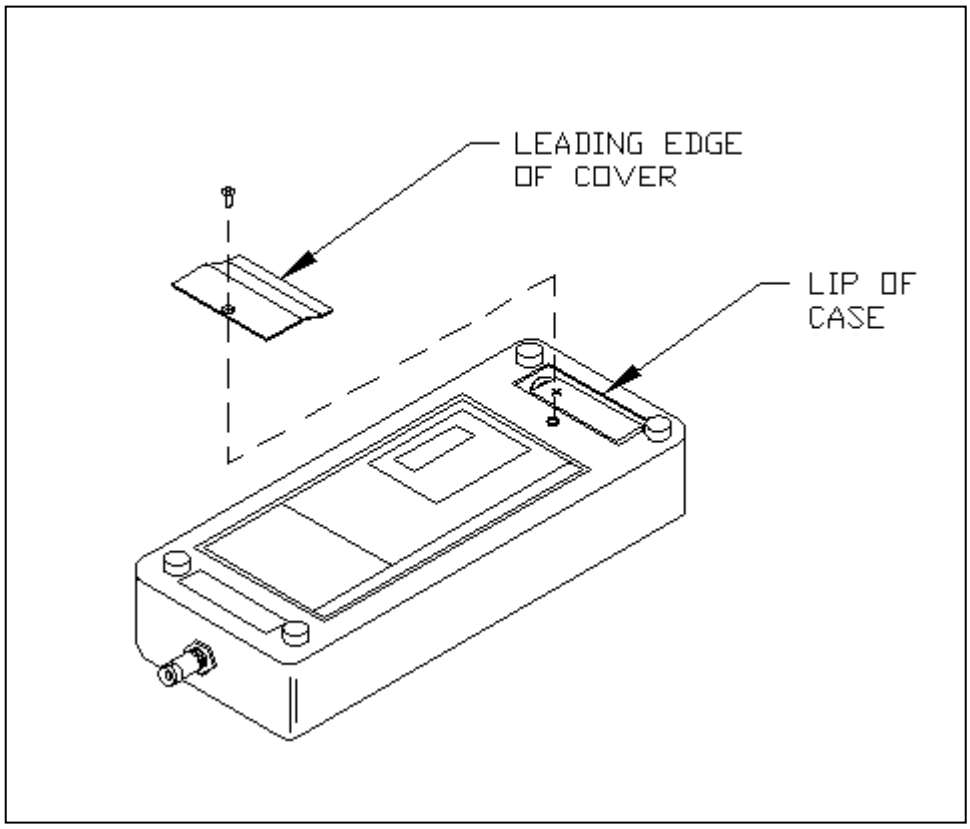

Figure 10-1. Battery Replacement for the Model 35080B kVp Divider

10.4 Calibration

WARNING

The factory calibration of the Model 35080B kVp Divider is performed with a precision high-voltage divider and a 12-bit ± 0.1% digital oscilloscope. If comparable equipment is not available, do NOT attempt to make adjustments on the kVp divider. Return the unit to the factory for adjustment.

Calibration of the Model 35080B kVp Divider depends primarily on the stability of the filter pack. (Review Section 3, Theory of Operation.) Since the filter pack primarily consists of metal sheets, the absorption is not expected to change with time. There are only two calibration adjustments in the kVp divider. One adjustment (RP103) sets the gain of the ratio circuit. The other adjustment (RP101) sets the ratio of the internal reference currents that are used as an internal calibration check when the function switch is set to the “CAL” mode.

INTERNAL CALIBRATION CHECK

1. Set the function switch to the ‘‘CAL’’ position.
2. Insert the Test Pack (32863).
3. The output voltage should read 0.750 volts ± 1%.

NOTE

Each 1% deviation of this value will result in no more than a 0.75% of reading error. This measurement must be made with a ± 0.1% DVM.

EXTERNAL CALIBRATION CHECK

1. Place the Model 35080B kVp Divider in the "RUN" mode. Insert the Test Pack (32863).
2. Place the kVp divider in the x-ray beam aligned as described in Section 4.5, Geometry of Setup. Make the focal spot to kVp divider distance 22 inches.
3. With a 100 kV, 200 mA exposure, the output should be 3 volts ± 1%.

NOTE

Most oscilloscopes are not accurate enough (0.1%) to make this measurement. Each 1% of miss-adjustment will cause a maximum of 0.75% of reading error.

CALIBRATION ADJUSTMENT

NOTE

Only facilities with precision calibration equipment should adjust the calibration of the Model 35080B kVp Divider.

1. Insert the Test Pack (32863). Place the Model 35080B kVp Divider on the x-ray table, such that the distance from the focal spot to the kVp divider is 22 inches, and the instrument is normal to the beam--with the long axis of the kVp divider perpendicular to the axis of the x-ray tube; this configuration will avoid "heel effect." Settings on the generator for kVp should be 100 kV and 200 mA.
2. With the kVp divider in the "OFF" mode, zero the oscilloscope.
3. Turn the mode switch on the kVp divider to the "RUN" position.
4. Make an x-ray exposure (greater than 1 mS duration for three-phase generating equipment--greater than 1 line cycle duration for single-phase generating equipment).
5. Accurately measure the peak voltage (± 0.1%). Record this value as "A".
6. If "A" falls outside of the range 2.970 to 3.030 volts, adjust the kVp divider, as follows.
7. Remove the kVp divider instrument case to access the adjustment potentiometers. Place the kVp divider in the "CAL" mode and measure the output voltage (± 0.1% accuracy). Record this value as "B".
8. With the kVp divider still in the "CAL" mode, adjust RP102 until the output is

   V = 3.000 x B/A volts.
9. With the instrument still in "CAL", adjust RP101 until the output = 0.750 volts.
10. Place the kVp divider back in its instrument case and turn the function switch to the "RUN" mode. Repeat Step 5. The value should be 3.00 volts ± 1%. If not, repeat the sequence.

NOTE

If the oscilloscope in use is not accurate to ± 0.1%, do not attempt adjustment of the Model 35080B kVp Divider.

OTHER ADJUSTMENTS

The third adjustment potentiometer (RP103) adjusts the amount of the waveform that is displayed by the oscilloscope. If annoying artifacts are observed on the oscilloscope, turning the potentiometer (RP103) counterclockwise will decrease the width of the waveform displayed on the oscilloscope. Turning the same potentiometer clockwise will conversely increase the width of waveform displayed. Refer to Figure 10-3 for an illustration of the effects of this adjustment.

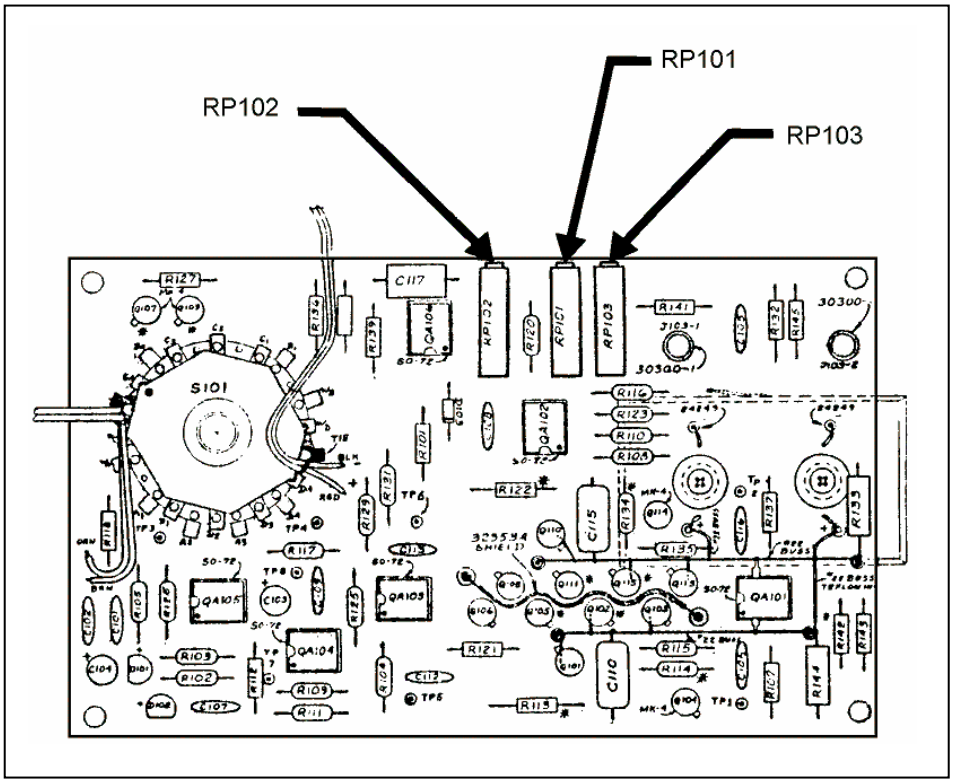

Figure 10-2. Location of RP101, RP102, and RP103

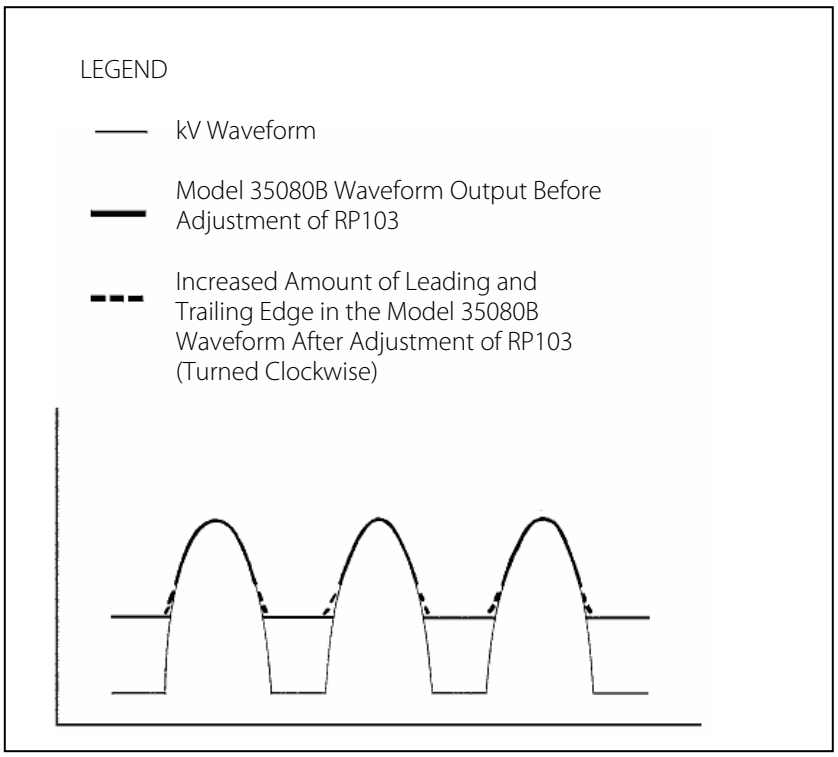

Figure 10-3. Effects of RP103 Adjustment

10.5 Replaceable Parts Information

Fluke Biomedical maintains a complete inventory of all normal replaceable parts (see Table 10-1). To place an order, or to obtain information concerning replaceable parts, contact the Fluke Biomedical at 440.498.2564 or by Fax at 440.542.3682.

Table 10-1. Replaceable Parts List

Description	Part Number
Power battery, 9.0 V, alkaline	16-29
Wide Range Filter Pack	37617
Test Filter Pack (Optional)	32863
Linear Mammo Filter Pack (Optional)	37351
Cadmium K-edge Mammo Filter Pack (Optional)	37355
CT Filter Pack (Optional)	33551
Mobile Filter Pack Plus (Optional)	37946
Low Range Filter Pack (Optional)	38237
Carrying Case	37423
Battery Cover	37842
Rubber Feet	38471

10.6 Recalibration & Repair Information/technical assistance

If your instrument needs recalibration or repair, we request that you contact Fluke Biomedical at 440.498.2564 or by Fax at 440.542.3682.

More information concerning the operation, application, or service of your instrument may be obtained from the applications engineer at the previously listed numbers.

10.7 Warranty Information

Should your instrument require warranty service, contact Fluke Biomedical at 440.498.2564 or by Fax at 440.542.3682.

NOTE

This warranty does not cover battery replacement or damage caused by battery leakage.

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Section A
Mammographic Measurements With The Model 35080B

A.1 Introduction

We recommend that the two mammographic filter packs, K-edge Mammo Filter Pack (37355) and Linear Mammo Filter Pack (37351) be used together. The K-edge Mammo Filter Pack (37355) is used first to find a point between 27.5 kV and 29.5 kV very accurately. Then, the Linear Mammo Filter Pack (37351) measurement is made at the same point to determine the necessary correction to apply to all readings taken with the Linear Mammo Filter Pack (37351). The K-edge measurement should be performed each time a generator is tested.

Part of the correction factor for the Linear Mammo Filter Pack (37351) is due to variations in tube filtration and part is due to positional dependence. Therefore, if the Model 35080B non-invasive kVp Divider is moved when using the Linear Mammo Filter Pack (37351), a new measurement at the K-edge comparison kVp point must be made with the Linear Mammo Filter Pack (37351) to compute a new correction factor.

The following procedure enables the first-time user to achieve good results. An experienced user can take many short cuts. The kVp divider with the mammo kVp option is for use on molybdenum anode, beryllium window tubes only.

A.2 K-Edge Measurement

MEASUREMENT SETUP

1. Remove the cone.
2. Remove the compression paddle, turn it upside down and reinstall as shown in Figure 5-3.
3. Place the Model 35080B kVp Divider (with a K-edge Mammo Filter Pack, 37355) on top of the compression paddle as close as possible to the x-ray tube.
4. Level the kVp divider.

OSCILLOSCOPE SETUP

1. Connect the Model 35080B kVp Divider to the scope using a shielded cable.
2. Set the vertical sensitivity to 0.5 volts per division.
3. With the input in the ‘‘GROUND’’ position, adjust the vertical position control to place the trace on the bottom graticule line.
4. Set the scope in single trace, storage mode.
5. Place the input selector switch in the ‘‘DC’’ position.

K-EDGE MEASUREMENT PROCEDURE

Part A

1. Set the x-ray generator for 25 kVp, 100 mA--or a mAs setting that provides the maximum tube current--at least 50 mA.
2. Select the Mo (molybdenum) filter.
3. Make an exposure, adjusting the scope trigger level as necessary to get a stable trace.
4. Measure the peak voltage and record in box A on the accompanying data sheet. (Figure A-2.)

Part B

1. Set the generator for 26 kVp and make an exposure.
2. Record this voltage value in box B on the data sheet (Figure A-2). (The voltage values, A and B, should be equal to within ± 0.020V; if so, this will be your BASE VOLTAGE; if not, then repeat the above steps, at one kVp lower.)

Part C

1. Set the generator for 29 kVp and make an exposure.
2. Measure the peak voltage. (If this voltage is greater than the BASE VOLTAGE by 0.1V but not greater than 0.25 V above the BASE VOLTAGE, record in box C (Figure A-2). If the voltage is greater than 0.25 volts above the BASE VOLTAGE, repeat this step at one kVp lower. If the voltage is not greater than the BASE VOLTAGE by 0.1 volts, repeat this step at one kVp higher.)

Part D

Repeat the last measurement to verify that the generator is repeatable. The voltage reading should repeat to within 0.020 V. If the reading is not repeatable, the generator needs service.

Part E

1. Subtract the BASELINE voltage from the voltage measured in Part C, step 2 (box).
2. Multiply this voltage by 10, add to 27.0, and record in box D (Figure A-2). This is the true kVp for this station.
3. Set the scope for single sweep, storage mode, and in the ‘‘DC’’ input mode.

NOTE

PROCEED TO LINEAR MEASUREMENT - DO NOT CHANGE THE GENERATOR SETTINGS.

A.3 Linear Measurement

MEASUREMENT SETUP

1. Replace the Cadmium K-edge Mammo Filter Pack (37355) with the Linear Mammo Filter Pack (37351).
2. Reposition the Model 35080 kVp Divider to approximately 15 inches from the focal spot (see Figure 6-3).

OSCILLOSCOPE SETUP

1. Set the vertical sensitivity to 0.05 volts per division.
2. With the input switch in the ‘‘GROUND’’ position use the vertical position control to place the trace on the bottom graticule line.

3. Set scope for single sweep, storage mode, and in the ‘‘DC’’ input mode.

LINEAR MEASUREMENT PROCEDURE

Part A

1. With the generator settings used for K-edge measurement in Part C make an exposure.
2. Record the voltage in box E (Figure A-2), then multiply the voltage in box E by 100 and record as kVp in box F.

Part B

1. Subtract the kVp in box F from the kVp in box D (Figure A-2). (This will be the CORRECTION VALUE applied to all kVp measurements made with the Linear Mammo Filter Pack, 37351C.)
2. Insert this value in all spaces in the column labeled ‘‘CORRECTION VALUE.’’

NOTE

This value may be either positive or negative.

Part C

1. Measure other kVp values as desired.
2. Enter the voltage in the ‘‘LINEAR VOLTAGE’’ column on the data sheet, multiply by 100.
3. Enter the value in the ‘‘LINEAR kVp’’ column.
4. Apply the CORRECTION VALUE to all kVp's by either adding to or subtracting from the ‘‘LINEAR kVp’’ column, and record the results in the ‘‘CORRECTED kVp’’ column. (This column now has the true kVp value for all kVp's measured.)

Part D

If the position of the Model 35080B kVp Divider changes during the Linear kVp measurement, you must repeat the measurement starting with Part C: some of the correction value is positional dependent.

Set kVp	K-edge Voltage	True kVp	Linear Voltage	Linear kVp	Correction Value	Corrected kVp
22	———	———	0.213	21.3	+0.8	22.1
23	———	———	0.221	22.1	+0.8	22.9
24	———	———	0.230	23.0	+0.8	23.8
25	(A) 3.10	———	0.237	23.7	+0.8	24.5
26	(B) 3.10	———	0.249	24.9	+0.8	25.7
27	———	———	0.255	25.5	+0.8	26.3
28	———	———	0.267	26.7	+0.8	27.5
29	() 3.26	(D) 28.6	(E) 0.278	(F) 27.8	+0.8	28.6
30	———	———	0.287	28.7	+0.8	29.5
31	———	———	0.299	29.9	+0.8	30.7
32	———	———	0.308	30.8	+0.8	31.6
33	———	———	0.319	31.9	+0.8	32.7
34	———	———	0.33	33.0	+0.8	33.8
35	———	———	0.342	34.2	+0.8	35.0
36	———	———	0.351	35.1	+0.8	35.9

Figure A-1. The Model 35080B Mammographic Worksheet (Example)

Set kVp	K-edge Voltage	True kVp	Linear Voltage	Linear kVp	Correction Value	Corrected kVp
22	_____	_____				
23	_____	_____				
24	_____	_____				
25	(A)	_____				
26	(B)	_____				
27	_____	_____				
28	_____	_____				
29	()	(D)	(E)	(F)		
30	_____	_____				
31	_____	_____				
32	_____	_____				
33	_____	_____				
34	_____	_____				
35	_____	_____				
36	_____	_____				

Section B
Correcting kVp Measurements For Gain Effects

B.1 Introduction

NOTE

Section 10.4, Calibration, of the Model 35080B kVp Divider user's manual details a method for performing gain corrections by adjusting the internal potentiometers of the instrument. This remains a completely acceptable technique. The purpose of this addendum is to provide an alternative method for users with sealed units, who cannot access the adjustment potentiometers.

The calibration mode feature of the Model 35080B kVp Divider provides a method to monitor the gain of the internal circuitry. When the kVp divider is placed in CAL mode, the specific voltage and kVp stated on each individual filter pack should be obtained. If the output voltage in CAL mode is not within ± 1% of the value stated on the pack, kVp measurements should be corrected in one of the following ways, depending on the device used for measuring the output of the kVp divider. A deviation of less than ± 1% will result in a maximum kVp error of 0.75% of reading.

B.2 Oscilloscope Measurements

The Model 35080B kVp Divider Instruction Manual describes the technique that should be used to measure kVp when connected to an oscilloscope (refer to Section 2.4). A slight modification of this technique will allow for the correction of gain effects. Briefly, this technique is as follows.

1. Insert the filter pack to be used into the kVp divider and connect to the oscilloscope. Set the oscilloscope gain to an appropriate value depending on the sensitivity of the filter pack.
2. With the function switch of the kVp divider set to OFF, adjust the oscilloscope vertical position such that the trace coincides with the bottom horizontal line on the screen. This line now corresponds to the Zero offset kVp given on the pack.
3. Switch the kVp divider to the CAL position. The oscilloscope trace should now be at a level corresponding to the CAL kVp given on the filter pack. If this is not the case, the gain effects should be corrected before making kVp measurements in the RUN position.
4. The gain effects can be corrected by adjusting the fine-tuning knob on the Volts/div switch of the oscilloscope. While still in the CAL position, adjust this knob until the trace on the screen corresponds to the kVp value expected for the filter pack in use. Measurements made in RUN mode will now be corrected for gain effects.

B.3 Voltmeter Measurements

If the output of the Model 35080B kVp Divider is connected to a voltmeter, a mathematical correction is required to compensate for gain effects. The first step in this correction process is to determine the expected and actual voltages when the kVp divider is placed in CAL mode. With the filter pack in place, switch the kVp divider to the CAL position and read the voltmeter to obtain the actual CAL voltage of the unit. The expected CAL voltage is the value listed on the filter pack itself. If these values do not agree to within ± 1%, perform the following correction for all subsequent kVp measurements made using this filter pack.

Voltages obtained in RUN mode will deviate from correct values by the same ratio as the deviation in CAL voltages. That is,

$$\frac{\text{Actual CAL Voltage}}{\text{Expected CAL Voltage}} = \frac{\text{Measured Voltage in RUN mode}}{\text{Corrected Voltage}}$$

where Corrected Voltage is the true voltage that would be obtained if the gain were accurate. Therefore, we can obtain a Corrected Voltage for any exposure by rearranging the above equation.

$$\text{Corrected Voltage} = \text{Measured Voltage}\left(\frac{\text{Expected Voltage in CAL mode}}{\text{Actual Voltage in CAL mode}}\right)$$

The corrected kVp is then calculated as usual by multiplying the Corrected Voltage by the sensitivity and adding the Zero offset kVp of the particular filter pack in use.

Example: A Model 35080B kVp Divider with a Wide Range Filter Pack (37617) (50-150 kVp) is connected to a voltmeter and switched to CAL mode. A value of 0.412 V is observed, which is 3% higher than the expected CAL voltage of 0.400 V for this pack. Therefore, subsequent measurements made with this pack should be corrected.

The kVp divider is now switched to RUN mode. An x-ray exposure is made, and a voltage of 0.515 V is measured. A Corrected Voltage is calculated from the previous equation.

$$\text{Corrected Voltage} = 0.515\text{V}\left(\frac{0.400\text{V}}{0.412}\right) = 0.500\text{V}$$

Using the sensitivity of 0.1 V/10 kV and 40 kVp Zero offset given for this filter pack, the Corrected kVp is 90. A kVp of 91.5 would have been measured if the above gain correction had not been performed.

B.4 The Model 35050A Dosimeter Measurements

The Model 35050A Dosimeter/kVp Readout automatically converts the output voltage of the Model 35080B kVp Divider to a kVp value, using the sensitivity and Zero kVp offset of the selected filter pack. Therefore, the method for calculating a Corrected kVp value is slightly different.

The first step again is to determine the actual and expected values with the Model 35080B kVp Divider in CAL mode. In this case, since the values are in kVp rather than raw voltages, the Zero offset value must be included in the calculation. The ratio equation in terms of kVp values is

$$\frac{\left(\text{Actual CAL kVp} - \text{Zero offset kVp}\right)}{\left(\text{Expected CAL kVp} - \text{Zero offset kVp}\right)} = \frac{\left(\text{Measured kVp in RUN mode} - \text{Zero offset kVp}\right)}{\left(\text{Corrected kVp} - \text{Zero offset kVp}\right)}$$

where the Expected CAL kVp and Zero offset kVp correspond to the values given on the actual filter pack. Note that the sensitivity need not be considered since it cancels out of the above equation. The Corrected kVp can be obtained directly from this equation by rearranging.

$$\text{Corrected kVp} = \left(\text{Measured kVp} - \text{Zero offset}\right)\left(\frac{\text{Expected CAL kVp} - \text{Zero offset}}{\text{Actual CAL kVp} - \text{Zero offset}}\right) + \text{Zero offset}$$

Example: For the Wide Range Filter Pack (37617) (50-150kVp), the Expected CAL kVp is given as 80, and the Zero offset value is 40 kVp. However, a Model 35080B kVp Divider in CAL mode with this filter pack inserted is connected to a Model 35050A Dosimeter, and a kVp of 81.2 is measured. When placed in an x-ray beam in RUN mode, the Model 35050A Dosimeter reads 91.5 kVp. The Corrected kVp for this exposure is calculated from the previous equation.

$$\text{Corrected kVp} = \left(91.5\,\text{kVp} - 40\,\text{kVp}\right)\left(\frac{80\,\text{kVp} - 40\,\text{kVp}}{81.2\,\text{kVp} - 40\,\text{kVp}}\right) + 40\,\text{kVp} = 90\,\text{kVp}$$

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Section C
Procedure For Making kVp Measurements On Rhodium Anode, Rhodium Filtration Selection Of GE DMR Mammography X-ray System

C.1 Introduction

The GE DMR mammography x-ray system has both molybdenum and rhodium anode selections. Measurements on the Mo anode track can be made in the same manner as on any other Mo anode mammography generator, provided Mo is also selected as the additional filter material. This involves using the Model 35080B Dosimeter and its two associated mammo filter packs, the Cadmium K-edge Mammo Filter Pack (37355) and the Linear Mammo Filter Pack (37351), as instructed in the Model 10100A TRIAD™ Field Service Kit Instruction Manual (37580) or the Model 35080B kVp Divider Instruction Manual (37648). This addendum is intended to provide a method to measure kVp on the rhodium anode track, with rhodium also selected as the additional filter material.

C.2 Procedure

NOTE

The automatic k-edge correction feature of the 35050A (available in firmware versions 11-Jan-95 and later) should not be used when following this procedure. When preparing to make measurements with the Linear Mammo Filter Pack (37351), be sure to press the RESET/MEASURE button twice, until the phrase “kVp NOT Corrected” appears on the top line of the Model 35050A display. All subsequent measurements made with the Linear Mammo Filter Pack (37351) should also have this phrase on the top line of the display. If you have an older version of the Model 35050A Dosimeter that does not provide automatic k-edge corrections, ignore this note.

Use the following procedure to measure kVp on the rhodium anode, rhodium filtration selection of the DMR.

1. Acquire a Cadmium K-edge Mammo Filter Pack (37355) measurement using the normal method to determine a value of kVp between 27.5 and 29.5 kVp. This value can be used without correction resulting in a maximum error of about 1 kVp. For maximum accuracy, use the look-up-table in Table C-1 to obtain a corrected value of kVp. For example, if the measured value of kVp were 27.8, the actual corrected value would be 28.2 kVp. This correction is due to the slight difference in response of the Cadmium K-edge Mammo Filter Pack (37355) to the Rh anode, Rh filtration spectrum as compared to a Mo anode, Mo filtration spectrum.

Table C-1. Look-up-table for Cadmium K-edge Mammo Filter Pack (37355) measurements made on Rh anode, Rh filtration selection of DMR mammography system. The equation used for the correction is Corrected kVp = (Uncorrected kVp - 27) x 1.5 + 27

Uncorrected kVp	Corrected kVp		Uncorrected kVp	Corrected kVp
27.3	27.5		28.2	28.8
27.4	27.6		28.3	29.0
27.5	27.8		28.4	29.1
27.6	27.9		28.5	29.3
27.7	28.1		28.6	29.4
27.8	28.2		28.7	29.6
27.9	28.4		28.8	29.7
28.0	28.5		28.9	29.9
28.1	28.7		29.0	30.0

2. Insert the Linear Mammo Filter Pack (37351) into the Model 35080B kVp Divider and acquire a kVp measurement using the same generator settings as used for the k-edge measurement in step 1. Use the look-up-table in Table C-2 to determine the actual kVp of the exposure. For example, if the measured value were 34.3 kVp, the actual kVp would be 28.7.
3. Determine the k-edge correction value as usual, by subtracting the Linear Mammo Filter Pack (37351) reading (28.2 in the example) from the measurement obtained with the Cadmium K-edge Mammo Filter Pack (37355) in step 1 (28.7 in the example). Note that the k-edge correction value can be positive or negative (the value is (28.2 - 28.7) = -0.5 kVp in this example).

Table C-2. Look-up-table for Linear Mammo Filter Pack (37351) measurements made on Rh anode, Rh filtration selection of DMR mammography system. The equation used for the correction is
Corrected kVp = (Uncorrected kVp x 1.2) - 12.5

Uncorrected kVp	Corrected kVp	Uncorrected kVp	Corrected kVp	Uncorrected kVp	Corrected kVp
30.5	24.1	33.9	28.2	37.3	32.3
30.6	24.2	34.0	28.3	37.4	32.4
30.7	24.3	34.1	28.4	37.5	32.5
30.8	24.5	34.2	28.5	37.6	32.6
30.9	24.6	34.3	28.7	37.7	32.7
31.0	24.7	34.4	28.8	37.8	32.9
31.1	24.8	34.5	28.9	37.9	33.0
31.2	24.9	34.6	29.0	38.0	33.1
31.3	25.1	34.7	29.1	38.1	33.2
31.4	25.2	34.8	29.3	38.2	33.3
31.5	25.3	34.9	29.4	38.3	33.5
31.6	25.4	35.0	29.5	38.4	33.6
31.7	25.5	35.1	29.6	38.5	33.7
31.8	25.7	35.2	29.7	38.6	33.8
31.9	25.8	35.3	29.9	38.7	33.9
32.0	25.9	35.4	30.0	38.8	34.1
32.1	26.0	35.5	30.1	38.9	34.2
32.2	26.1	35.6	30.2	39.0	34.3
32.3	26.3	35.7	30.3	39.1	34.4
32.4	26.4	35.8	30.5	39.2	34.5
32.5	26.5	35.9	30.6	39.3	34.7
32.6	26.6	36.0	30.7	39.4	34.8
32.7	26.7	36.1	30.8	39.5	34.9
32.8	26.9	36.2	30.9	39.6	35.0
32.9	27.0	36.3	31.1	39.7	35.1
33.0	27.1	36.4	31.2	39.8	35.3
33.1	27.2	36.5	31.3	39.9	35.4
33.2	27.3	36.6	31.4	40.0	35.5
33.3	27.5	36.7	31.5	40.1	35.6
33.4	27.6	36.8	31.7	40.2	35.7
33.5	27.7	36.9	31.8	40.3	35.9
33.6	27.8	37.0	31.9	40.4	36.0
33.7	27.9	37.1	32.0		
33.8	28.1	37.2	32.1		

4. For all subsequent measurements at other generator settings, use the following procedure. First, obtain a reading using the Linear Mammo Filter Pack (37351). Next, determine the actual kVp using the look-up-table at the end of this application note. Finally, add the k-edge correction value calculated in step 3 to this value. This procedure will allow kVp measurements over the range of about 25 to 35 kVp. The example at the end of this addendum show a sample measurement session with all of the appropriate corrections applied.
5. When using an oscilloscope as the readout device for the kVp divider, first convert all measured voltages to kVp using the standard gain and offset for each filter pack. Then these measured values can be converted to actual kVp values using Tables C-1 and C-2.

Example: The chart below gives a set of sample kVp measurements made following the procedure outlined previously.

K-edge reading uncorrected	K-edge reading corrected (Table C-1)	Linear pack reading uncorrected	Linear pack reading corrected (Table C-2)	K-edge correction value	Corrected kVp measurement
27.8	28.2	34.3	28.7	-0.5	28.2
		32.2	26.1	same as above*	25.5
		38.3	33.5		33.0

* Once the k-edge correction value is determined, all subsequent measurements in the same session *will use this same value. It is not necessary to repeat the k-edge measurements in the same session unless the Model 35080B kVp Divider is moved.*

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