



Theory of Operation and Service Guide For Single-Phase Generators

Applies to control model numbers A300, A360, B300, B360, F280, K240, 01210, 01200, 02221 and 02222 that utilize the model A700 high voltage transformer.

This document provides useful background information and practical service tips about our single-phase radiographic generators. Our goal is to provide you with a greater sense of familiarity and confidence when working with our products, resulting in improved service efficiency with less effort.

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1. CONNECTIONS

a. Bucky

i. 36" bucky

Bucky	B1	B2	B3	B4
Generator	B1	B2	B3	B4

ii. 17" bucky (without a B8 terminal)

Bucky	B1	B2	B3	B4
Generator	B1	B2	B1	B4

iii. 17" bucky (with a B8 terminal)

Bucky	B1	B2	B3	B4	B6	B8
Generator	B1	B2	B1	B4	GND	B3

b. Stator (requires "R" type stator) and thermal switch (T5 to T6 of TB3)

- i. 07 mains (typically black) to 07 of TB3
- ii. 08 phase (typically red) to 08 of TB3
- iii. 09 common (typically white) to 09 of TB3
- iv. The color code may not always be as described. For an "R" type stator the resistance from 07 to 09 is 25-30 ohms, resistance from 08 to 09 is 50-60 ohms, and from 07 to 08 it is the sum of the two previous values, 75-90 ohms. Thermal switch connects to T5 and T6 of TB3. Other stator values may require a modification to the A455 motor start board.

c. Filament cable (to high voltage transformer)

- i. XL white
- ii. XS green (do **NOT** connect to ground!)
- iii. XC black
- iv. M1 red (note that the spark gap is about 0.012" from lid of tank)

2. THEORY OF OPERATION

a. The line voltage is applied to an autotransformer. Once tapped properly for the supply voltage all secondary autotransformer voltages are predictable.

- i. Nearly all functions operate from 120 VAC as measured between F1 and F2 of TB3 and TB2, fused for 8 Amps. No internal voltages are



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- referenced to ground. F1 is the common voltage reference point for logic and filament measurements.
- b. The stabilizer transformer “TS” is the 120 VAC constant voltage supply for the filament circuit. The output voltage goes through a boost resistor and adjustable bands on the filament resistors to control the amount of filament voltage as measured at XC/XL (large filament) or XC/XS (small filament).
 - c. The TSCC space charge compensation transformer adjusts the filament voltage slightly for different kVp settings. Proper space-charge compensation adjustment via the RSCC resistor bands creates a balanced mA level at high and low kVp settings.
 - d. PREP/EXP switch. The F2 potential, 120 VAC as referenced to F1, is present at idle at terminal S1 if the interlock terminals T5, T6, T7 are closed. When the switch is pressed to the first position, the F2 voltage passes to S2 and the motor start board at J6-8, starting the PREP sequence. When the switch is pressed to the second position, the F2 voltage is passed to S3, the exposure switch start signal.
 - e. PREP and the Motor Start Board. (Parts referenced are on A455 board)
 - i. When the A455 motor start board gets a 120 VAC input at pin 8, K1 will energize to apply 240 VAC to the x-ray tube stator during the “boost” stage of prep. After a time delay of 1.5 seconds, set by the time constant of R17 and C4, K1 drops out K2 and pulls in to remove the 240 VAC “boost” voltage, and engage the 50 VAC “run” voltage.
 - ii. If the rotor current during the “boost” and “run” stages of prep are determined satisfactory, K4 will energize and the red LED on the motor start board will illuminate. The contacts of the K4 relay pass 120 VAC (from S3 of the exposure switch) from J6-7 to J6-11 of the board. The 120 VAC continues through the bucky switch (waiting for B1/B2 contact closure of the bucky) or directly to J1-9 of the timer board to initiate exposure. If the LED does not light, K4 does not pass the 120 VAC exposure start signal to the timer.
 - f. Other actions from the Motor Start Board
 - i. At the start of prep, a contact closure between J6-3 and J6-5 bypasses a section of the filament boost resistor to increase the filament voltage from about 25 VAC in idle to a boost value of near 38 VAC at XC/XS (100 mA) or 51 VAC at XC to XL (300 mA).



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- ii. A contact closure at J6-6/J6-9 of the motor start board goes to the timer board at J1-6/J1-7 to indicate prep has begun.
- g. The timer board constantly monitors system status. When voltage is sensed across the back-up contactor during idle, the generator assumes this voltage comes from a leaking SCR. As measured at J1-8 and J1-10 on the timer (coming from the open contacts of the back-up contactor, wires 8B and 10B), any voltage above 2 or 3 VAC at this point will illuminate the “tube limit” light on the operator console and prevent exposure. The “limit light” will also illuminate if kVp, mA or time are set outside of tube limits. When the “limit light” is ON exposure is inhibited.
- h. EXPOSURE and the timer board. (Parts referenced are on timer board.)
 - i. If all the system status inputs to the timer board are good, a 120 VAC exposure start voltage at J1-9 energizes K2 on the board.
 - ii. The contacts of K2 energize K1, which passes 120 VAC to the coil of the back-up contactor, located on the electrical chassis.
 - iii. The timer board creates SCR drive pulses.
 - iv. The SCR drive pulses are counted and compared to the pre-selected pulse count code input at J5.
 - v. Once the elapsed SCR drive pulse count equals the pre-selected pulse count, the exposure stops.
- i. Note that the timer is a pulse counter. These single-phase generators can only expose in increments of 8.3 milliseconds. Often a triggering threshold on non-invasive meters makes it appear the exposure is consistently 4 milliseconds shorter than selected.
- j. Once the exposure is completed, the mAs display changes from a steady indicator of mAs to a flashing display of pulses counted during exposure. For example, if the exposure time is 1/10th of a second, post exposure mAs display will flash “12”, to indicate a 12 pulse exposure was made, regardless of the pre-exposure mAs selection. On units manufactured after December 2004 the mAs display will also display error codes, described in the troubleshooting section.



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3. CALIBRATION (mA)

- a. The mA output depends upon the filament voltage as measured from XC to XL (large spot) or XC to XS (small spot). More filament voltage means more filament current, resulting in a brighter filament and more mA.
- b. XC to XL for 300 mA (large) will be near 51 VAC during prep
- c. XC to XS for 100 mA (small) will be near 38 VAC during prep
- d. Because the tube conducts more current at higher kVp, the space charge compensation adjustment is set to make mA equal across the kVp range. This is achieved by generating a slightly higher filament voltage at low kVp, and a slightly lower filament voltage at high kVp. Increasing the space charge compensation will decrease the mA at high kVp. The filament voltage change is typically around 1.5 VAC between 80 kVp and 120 kVp.
- e. **AC** mA or mAs can be measured by inserting a meter in series with the red M1 lead from the high voltage transformer. If the spark gap on the transformer is touching the lid, x-ray will be produced but no mA will be measured. The gap must be between 0.010" to 0.013", or about equal to the thickness of a piece of radiographic film.
- f. Needing filament voltages higher than those described above likely indicate improper mA measurement or a resistive HV cable.
- g. As **AC** mA returns to the control at M1 during exposure, it travels through a bridge to the mA meter on the operator panel, and through the auxiliary coil of the on/off circuit breaker. If the mA level is excessive, the breaker will trip. The breaker will also trip if the line current is too high.

4. CALIBRATION (kVp)

- a. The kVp output depends upon the primary voltage selected by the kVp major/minor tap switches (and accurate mA calibration). Measuring the no-load voltage across the tap switches allows prediction of the actual kVp output for specific mA values, providing that the line voltage drop is low and mA output is correct.



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- b. The kVp meter is adjusted via the kVp compensation board to match the actual kVp output.
- c. The chart below has rows of mA and columns of kVp. The intersection points represent the tap switch voltage that will generate an expected kVp for each mA level. This allows the installer to select an mA station, the specific tap switch voltage for a desired kVp, and then fine-tune the kVp compensation board to make the kVp meter to match actual output.

This chart is valid for all the single-phase generators Summit manufactures (Nova, Spectra, private labeled 325/360 models, InnoVet Classic/Select).

Tap Switch Voltage to kVp output matrix	50 kVp	80 kVp	120 kVp
50 mA	104 VAC	157 VAC	228 VAC
100 mA	106 VAC	160 VAC	229 VAC
150 mA	112 VAC	167 VAC	238 VAC
200 mA	126 VAC	180 VAC	250 VAC
300 mA	155 VAC	207 VAC	278 VAC

The tap switch voltages above will produce the kVp shown if the mA level is correct and the line voltage drop is less than 5%.

On single-phase generators kVp and mA are interactive. This means that for a specific tap switch voltage shown above the kVp output will be low if the mA is high. Conversely, for a specific tap switch voltage shown above the kVp output will be high if the mA is low.

- d. Note that the primary voltage (at the tap switches and P1/P2) is not stabilized, but dependant upon the stiffness of the incoming line voltage. If the line voltage drops under higher power exposures, so will the primary voltage and the kVp output. This will adversely affect kVp accuracy and linearity.



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5. TROUBLESHOOTING

Talk to the equipment user.

While the information may not be fully accurate or complete, often the solution can be determined with some well placed questions prior to arrival on site.

- a. Is the “Tube Limit” light on? (see step a below)
 1. What is in the mAs display?
 2. Is it steady or flickering?
 3. Is it specific to one mA station?
- b. Can the kVp meter needle position be controlled? (If no, see step b)
- c. Does the anode of the tube “spin up” at prep? (refer to step c below)
- d. At exposure request is there a beep? (If NO, see step d below).
- e. At exposure request there is a beep? (if YES, but the film is clear, step e)
- f. Are the films dark, light or erratic in density? (refer to step f below)
- g. At exposure does the unit “groan” or circuit breaker trip? (refer to step g)

a. Error codes, “tube limit” light, blank/flickering mAs display.

On units manufactured after December 2004 (or with 02249 timer) the digital mAs display includes error codes to indicate the cause of the “tube limit light”.

Error Code	Indicated Fault	Corrective Action
E01	Tube Limits Exceeded	Reduce kVp, mA or Time
E02	kVp too high (>128 kVp)	Select 125 kVp or less
E03	kVp too low (<37 kVp)	Select 40 kVp or more
E04	Invalid mA setting	Reselect mA station
E06	Invalid Time Selection or Leaking SCR	Reselect Time station, call for service if error won't clear.

For older units if the “tube limit light” is on, the digital mAs display will go blank. The solution is the same as above. Find the input to the timer board that is missing or out of range, determine if the SCR is leaking, or if P1/P2 is grounded.

- i. The SCR is leaking if more than 3 VAC can be measured across the back-up contactor when generator is in “idle” or standby mode.
- ii. The mA selector input is missing. At J4 of the timer board a closure of pin 3 to pin 4 selects 300 mA.
- iii. The time select input is missing. At J5 of the timer board a closure of pin 1 to pin 10 to pin 18 selects 1/60 sec.



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- iv. The same AC voltage measured across the inputs to the kVp meter must be present between J1-3 and J1-5 of the timer board.
- v. P1 and P2 to ground are open (infinite resistance with power OFF).
- vi. Symptom of erratic or flickering mAs display, often with “limit” light.
 - 1. Loose connections to mA selector switch
 - 2. Loose cable or wire on mA or time input to timer board
 - 3. Loose kVp meter voltage wire at timer board
 - 4. Noisy or low 5 VDC supply on timer board
 - 5. Digital mAs display board or cable (if erratic with no limit light)

b. Can the kVp needle position be controlled?

- i. Can the kVp meter needle position be affected by changing the tap switches, and if so, does it clear the “limit” light? (poor tap switch contact or technique selected outside of 40 – 125 kVp range).
- ii. If the kVp meter is “dead” at zero kVp, is it specific to one mA station or across all mA stations?
 - 1. An open kVp comp pot will prevent voltage from getting to the kVp meter. This is usually the case if the “dead” kVp meter is specific to one or more mA stations, particularly on units made prior to September 2003. An open slope pot will make the meter indicate zero kVp on one or both focal spots.
 - 2. This can also be caused by a poor wire-to-switch contact at the mA selector switch, and is the most likely cause on units made after September 2003.
 - 3. Jumpering the mA selector switch input to the kVp comp PCB will determine if switch/contacts or PCB is at fault.
 - a. Select an mA station where needle points to zero.
 - b. On the kV comp board jumper wire “1K” to the 150B wire (for 150 mA), or other mA station affected.
 - c. If kV meter needle reacts, replace the board.
 - 4. If the needle is physically stuck, replace the meter.

c. Does the anode “spin up” at prep?

- i. If not, confirm the following (located on chassis, TB2 or TB3)
 - 1. 120 VAC between Fuse 1 and Fuse 2, tight connections on all F1 and F2 terminals of the chassis terminal strips.
 - 2. 120 VAC between F1 and S1 in idle (closed interlock switches).
 - 3. 120 VAC between F1 and S2 in prep (exposure switch).
 - 4. Proper resistance between 07/08/09, measured at the control (stator cable continuity).



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d. No exposure, no beep

If the "limit" light is on, mAs display is blank or shows an error code go to "error codes step b" above. Otherwise, confirm signals as described below, listed in order of suspicion.

- i. The red LED on the motor start board **must** illuminate at the end of prep. Confirm the motor start board transitions from 240 VAC "boost" to 50 VAC "run" as measured between stator terminals 07 and 09 of TB3. If the voltage stays at 240 VAC there is an open R17 or shorted C4 on the motor start board.
- ii. There may not be 120 VAC at S3 (referenced to F1) during exposure request due to an open interlock, F1 or F2 fuse, or exposure switch.
- iii. Poor contacts on motor start board J6-7/J6-11 or bucky switch causing no 120 VAC start voltage to timer at J1-9. (The light on the motor start board indicates relay coil voltage, not contact closure.)
- iv. The motor start board may sense an improper amount of rotor current due to stator resistance, 07/08/09 connections or bad stator cable.
- v. The motor start board may be defective in another way
 1. Failing to sense proper rotor current.
 2. No contact closure between J6-6/J6-9 at prep

e. At exposure request the unit beeps but the film is clear.

All the logic is satisfied. This means there is either no primary voltage (no kVp) or no filament current (no mA).

- i. Lack of primary voltage (kVp) may come from failure to engage the back-up contactor or SCR. Typically a connection problem, not a component failure.
- ii. Lack of filament voltage (mA).
 1. Check the XC/XS (100 mA) and XC/XL (300 mA) voltages in idle and in PREP. They should idle at about 25 VAC, and boost to between 38 and 51 VAC, respectively.
 - a. If the filament voltage is at or near 120 VAC, there is an open in the secondary. Suspect the cathode cable or the x-ray tube.
 - b. If the filament voltage is at or near zero, there is an open in the control, possibly a resistor band connection, mA selector switch/connector, no output/input to TS filament transformer, or F1/F2 fuses.



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- c. If the voltage in idle is low, and gets lower when boosted, the problem may be a short within the high voltage transformer, filament cable or cathode cable. Isolate to identify.
- d. If the idle voltage is normal but does not boost, there may be no closure between J6-3/J6-5 of the motor start board or a poor connection on the boost resistor bands.
- e. If the voltage is higher than normal (eg. 70 VAC at prep) and the mA output is low, suspect a resistive quality to the cathode cable. In this case mA will be very low or absent from poor filament illumination.

f. Films are dark, light or erratic in density

- i. Confirm kVp, mA and time accuracy.
- ii. Confirm proper and consistent radiation output
 - 1. At a 40" SID and 80 kVp expect about 3.5 mR/mAs
 - 2. Results should be consistent for each mA station.
- iii. Confirm operator's consistent technique selection
- iv. Check processor for chemical quality, consistent temperature and transport speed.
- v. Confirm cassettes darken film equally with same exposure factors.
- vi. Check darkroom for light leaks, fogged film.

g. At exposure the unit "groans" or circuit breaker trips

- i. Identify the existence of high-voltage breakdown (hypot test). This problem usually occurs above a specific kVp level.
 - 1. Remove the high voltage cables from the transformer and fill the cable receptacles with oil. Inspect the cable ends for carbon, evidence of arcing.
 - 2. Place an AC mA meter in series with M1 lead of filament cable.
 - 3. Select 80 kVp and make exposures. If mA is produced during exposure, the diode sticks in the transformer must be replaced.
 - 4. If there is no mA produced during the hypot test of the transformer, the high voltage cables or x-ray tube are arcing. When the cables have been reconnected to the transformer observe the following:
 - a. If a "snap" can be heard during exposure, the cables are suspect.
 - b. If a blue or purple flash can be seen from the port of the x-ray tube, the tube is suspect.



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- ii. Identify a half-waving generator or transformer.
 1. With the generator “on” but in idle, select a low kVp, low mA and long exposure time. Select a low kVp, low mA and long exposure time.
 2. Measure the AC voltage between the common poles of the kVp tap switches during idle. Measure the AC voltage between P1 and P2 of the transformer during exposure. If the P1/ P2 voltage during exposure is only half of the tap switch voltage during idle, the SCR is half-waving. Confirm SCR gate leads.
 3. If the P1/P2 voltage is the same as the tap switch voltage:
 - a. Select 100 mA, 1/10th of a second, 70 kVp. Verify about 38 VAC between XC and XS at prep. If 5 mAs (AC) is measured during exposure the transformer is half-waving. Replace the diode sticks.
- iii. Does the problem get worse at higher mA levels?
 1. Excessive mA can create a large line voltage drop on a properly sized power supply system. **The mA measured in series with the red “M1” lead is AC mA.** Only 38 VAC (measured XC to XS in prep) is required to produce 100 mA, and about 51 VAC (measured XC to XL) is required to produce 300 mA. If measuring mA with the meter set to DC, only half of the actual mA output will be measured. This would create low kVp and a large line voltage drop. The circuit breaker would likely trip at or above the 200 mA selection.
 2. A large line voltage drop during exposure can create a heavy “groan” that worsens as exposure times increase.
 - a. Measure the line voltage between L1 and L2 in idle.
 - b. Measure the voltage between L1 and L2 during an exposure of 100 mA, 80 kVp, one second.
 - c. Measure the voltage between L1 and L2 during an exposure of 300 mA, 80 kVp, one second.
 - d. The line voltage drop during exposure should not be more than 5% of the no-load voltage.
 - e. If the load voltage drop is excessive, the power supply system requires upgrading.