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GE Power Systems
Energy Services

Partial Discharge Analysis System

Installation and Operation

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I. INTRODUCTION

Partial discharges take place in all high voltage equipment be it rotating or stationary. The discharges are high frequency (40–100 Mhz) low voltage discharges which maybe triggered by any number of equipment operating conditions. The measurement and analysis of partial discharges in rotating equipment may be used to monitor this activity to determine trends on specific machines and/or compare activity in identical machines as a basis for condition–based maintenance or avoidance of machine forced outages. Although the measurement and analysis of partial discharges is not new technology, the recent development of a proprietary phase–resolving analyzer and the use of three (3) phase plus a neutral (where required) capacitive coupler has resulted in the ability to provide a comprehensive, more accurate picture of machine condition. Systems which are not based on phase–resolved technology do not provide a total picture of the insulation's condition.

Over the years it has been determined that there are a number of adverse conditions which may develop and result in increased partial discharge activity, among them are:

- Aging of stator bar insulating materials resulting in voids in the insulation.
- Stator bar vibration and/or abrasion. In cases where insulation abrasion has been noted, heavy oil contamination has also been noted.
- Damage to the end winding voltage suppresser system (grading system).
- End winding contamination and corona.
- Connection ring vibration.
- Broken conductors.
- Collector brush sparking.

The PDA (Partial Discharge Analysis) system can provide a relative assessment of generator operating condition by performing on-line monitoring and trending of PDA activity resulting from some or all of the outlined adverse conditions. Some of the benefits of utilizing PDA are:

- Non-invasive
- May be performed on- or off-line.
- Indicates condition of generator insulation system.
- Identifies detrimental trends.
- Compares identical units aids outage planning.
- Augments conventional test and inspection methods
- Provides for condition-based maintenance.

II. EQUIPMENT DESCRIPTION

PDA equipment consists of three or four sensors (couplers) which are installed in the iso-phase bus duct of the generator and are connected to the line leads (and the neutral if required), see Figure 1.

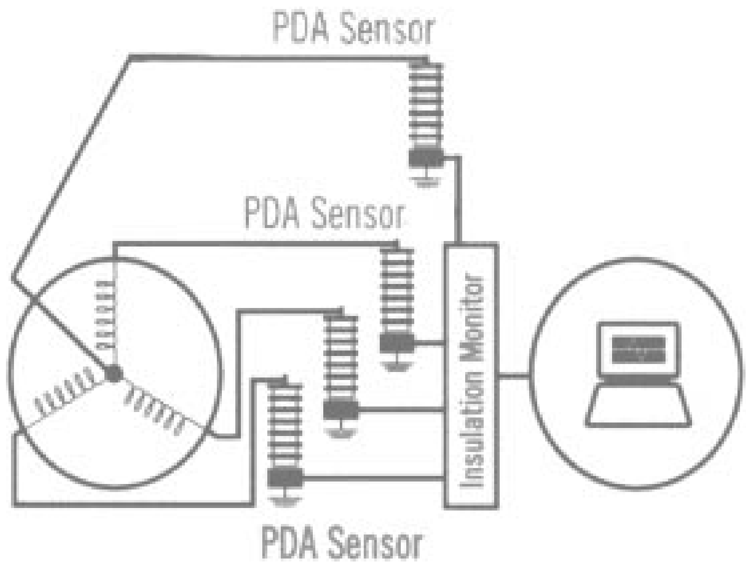


Figure 1. PDA System Schematic

Each sensor is comprised of two capacitors encased in a bushing and a high frequency current transformer (HCT) as shown in Figure 2. The sensors are grounded and the HCTs connected to a data interface/acquisition box, Figures 3, which may provide monitoring of the insulation PDA activity in any of the following ways depending upon the equipment that was purchased:

- Real time monitoring of the signal on an LCD display at the interface box, Figure 4.
- Local monitoring and recording (trending) of the signal with a PC laptop running ICM software.
- Remote monitoring and recording (trending) of the signal with a PC laptop with ICM software via an optional modem.

III. EQUIPMENT INSTALLATION

This section details the installation procedure for the PDA system. Personnel involved in the installation should have been involved in a prior PDA installation or been provided training. Operators must:

- Obey the regulations outlined by GE and the specific power plant regarding high voltage testing.
- Possess an understanding of how partial discharge occurs.
- Understand how to run software in the Windows environment.

A. References

The following references can be used for technical clarification.

IEEE Std. 510–1983, Recommended Practices for Safety in High-Voltage and High-Power Testing.

ANSMEEE Std 4–1978, IEEE Standard Techniques for High Voltage Testing, ASTM–D1868–81 Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems.

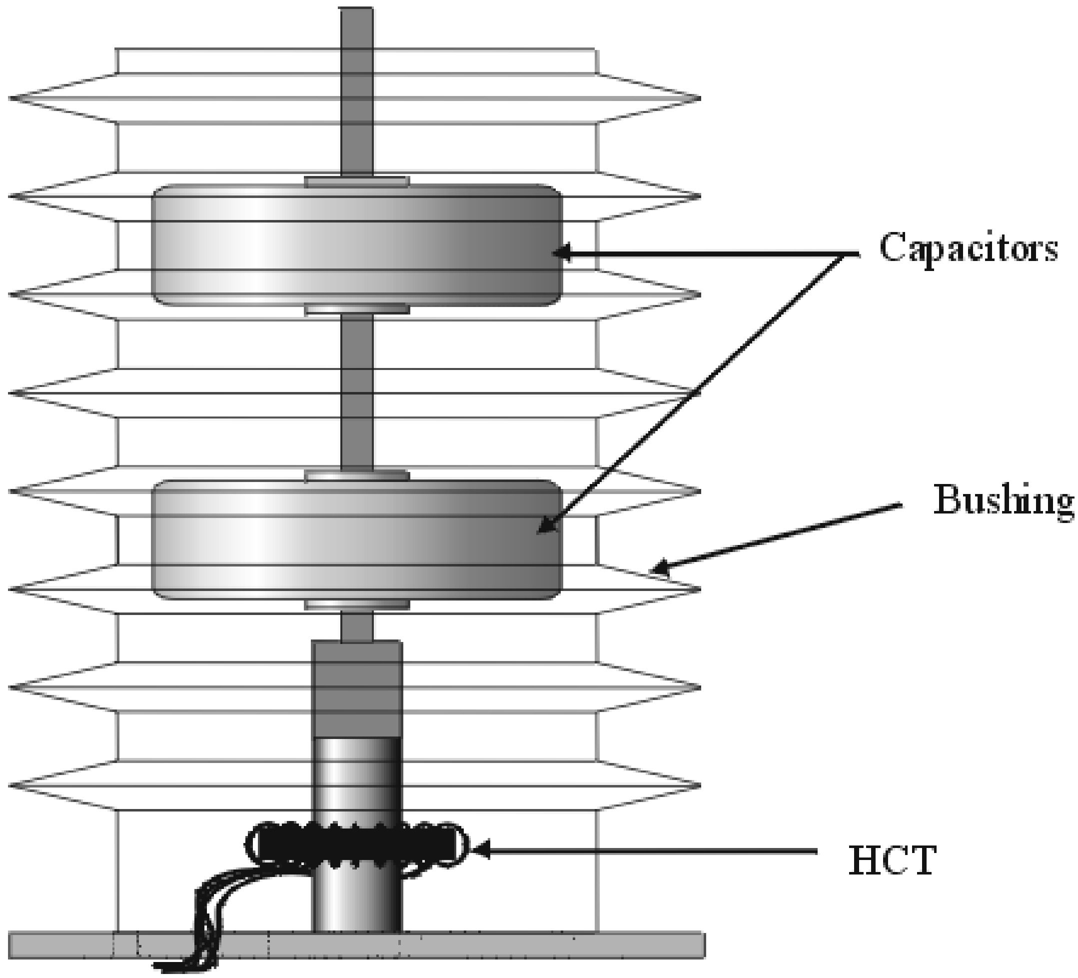


Figure 2. PDA Sensor – Internal Construction Shown

B. Tools and Equipment Required

- Digital volt meter.
- Digital storage oscilloscope: HP545 I OB.
- Coaxial cable crimp kit or wrenches for non-crimp terminations.
- Standard field tool kit (wrenches, screwdrivers, etc.).
- Coupling capacitors.
- Doubly shielded coaxial cable.
- 50 W coaxial cable terminators.

ICM System:

- One 486 Laptop running with ICM PDA v2.52 software.
- One ICM Amplifier unit RPA2 preamplifier (see Figure 5).
  - ▶ Four are required for on-line tests depending on accessibility to neutral.

Figure 3. Standard PDA Terminal Box

- High frequency current transformers (HCTs).
  - ▶ Four are required for on-line tests depending on accessibility to neutral.

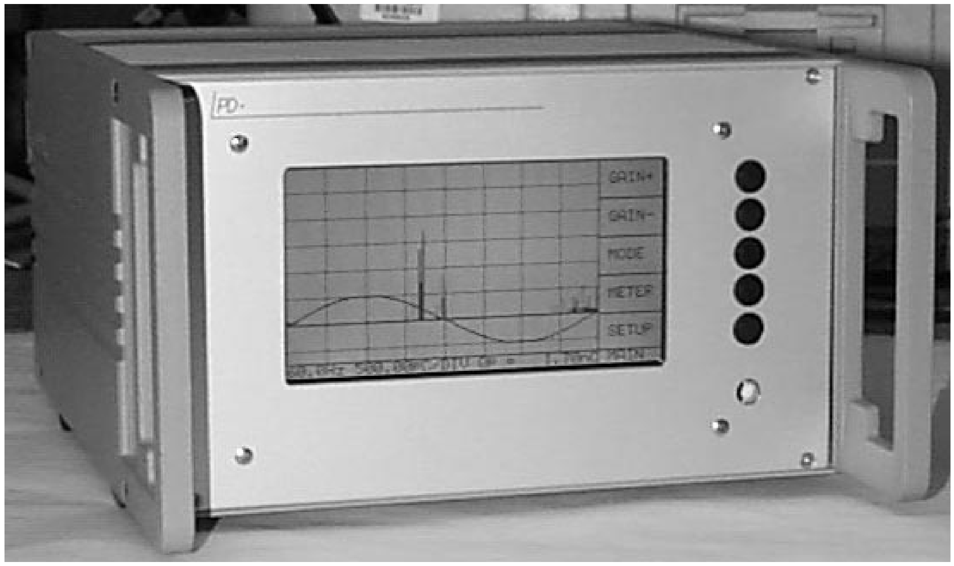


Figure 4. PDA Local Signal Monitor (LCD)

Figure 5. RPA 2 Preamplifier

- Interface cable between RPA2 and ICM Compact 15′RG58 coaxial cables.
  - ▶ One RG58 coaxial cable only, as short as possible for connecting the sensor to the RPA2.
- One partial discharge calibrator: Power Diagnostics Model CAL 1B (see Figure 6).

C. Installation Prerequisites

Prior to the installation, appropriate lock-out and tag-out procedures should be followed to ensure that no High Voltage is present at the installation site.

D. Customer Support Requirements

The utility or end-customer must provide two electricians who will drill and tap appropriate holes for mounting the sensors, mount the terminal box and run the cabling through customer supplied <u>non-conductive</u> conduit.

Customer will also provide access to 120/240 v for equipment operation as required.

Figure 6. CAL 1B Partial Discharge Calibrator

E. Equipment Installation

The outlined installation instruction is intended to summarize the work scope for installation of PDA equipment at a customer site. The instruction is for permanent installations only and all connections will be external to the generator.

CAUTION

Prior to making any connections, ensure that the stator armature winding has been discharged to ground and voltages are not present.

Based on past experience, it has been determined that to provide the most comprehensive and accurate data the PDA system couplers must be connected to the generator phase connections as close to the generator output bushings as is physically and safely possible. Recent installations on large generating units have shown that a convenient location for mounting the couplers has been inside of the iso-phase bus ducts. The fact that the generator neutral enclosure is usually located below the terminal box makes either of the two locations preferable.

In some instances, primarily on packaged and smaller generating units the generator output terminals may be located either on top or below the machine. Neutral grounding components are usually located within specified distances and the PDA connection box may be mounted in the exciter housing or an auxiliary enclosure.

NOTE

PDA Coupler mounting locations and PDA Terminal Enclosure should be within 25′ of each other for best optimum results.

When connecting PDA couplers, the following electrical clearances, which have been developed based on Power System experience and Electrical Standards, should be met.

RECOMMENDED ELECTRICAL CLEARANCES: PDA INSTALLATION			
MACHINE TERMINAL VOLTAGE	**CLEARANCE TO GROUND (MINIMUM) INCHES**	**CLEARANCE – COMPONENT SAME PHASE (MINIMUM) INCHES**	**CLEARANCE BETWEEN PHASES (MINIMUM) INCHES**
12–15 kV	6.00	5.50	6.00
15–18 kV	7.00	5.50	7.00
18–21 kV	7.75	5.50	7.75
21–24 kV	8.50	5.50	8.5
24–27 kV	9.25	5.50	9.25
27–30 kV	10.00	6.50	10.00

NOTE

Clearances are for bare conductors to ground – clearances may be reduced by use of additional electrical insulation.

As all installations are site-specific, the general installation guidelines outlined below for PDA applied to a large generating unit can be applied:

Drill holes in the enclosure for mounting the PDA coupler. Mount and connect the couplers to the iso-phase buss or to the bushing connectors using a conductor made of twisted bare stranded wire with a terminal lug connected to each end. The conductor size should be approximately that of # 12 AWG. The base plate of the coupler is electrical ground. Care should be taken to ensure that good contact is made between the base and the grounded bus duct.

In addition to the mounting holes, a hole for a non-conductive conduit coupler will be required. The HCT outputs are terminated at the base of the coupler as two pigtails. These pigtails are to be soldered onto the insulated BNC bulkhead connector, which in turn, is mounted on the base provided. The output lead tagged with white shrink tubing should be connected to the center pin of the BNC bulkhead connector and the remaining lead connected as the shield. The Coaxial HCT signal cable will be routed to the PDA connection box inside of PVC conduit. Connection to the PDA box may be by Flexible conduit components.

NOTE

Conduit between PDA Couplers needs to be electrically isolated from each other so that circulating currents do not flow between the phases.

Locate the PDA terminal connection box at a location which meets the minimumdistance criteria outlined previously. Drill four (4) mounting bolts for concrete anchors or other mounting means. Mounting procedure will be a function of location. Prior to mounting the connection box in it’s final location, a hole must be drilled either top or bottom for mounting of a conduit coupler. Mount the connection box and rout the conduit from the PDA couplers to the box and connect the conduit coupler. Connect the PDA coupler BNC connectors to the proper input connectors and close the connection box. Connection box to be re-opened only when taking data.

IV. STANDARD OPERATING PROCEDURES FOR ON-LINE/OFF-LINE ELECTRICAL DISCHARGE ANALYSIS USING THE ICM TEST SYSTEM

A. Scope

This section describes the procedure for making phase resolved partial discharge measurements using the ICM test system software version 2.41.

B. References

The following documents shall be considered part of this instruction to the extent specified herein. Unless otherwise stated, the latest revision shall apply.

IEEE P1434 *Guide to Performing Partial Discharge Analysis on Rotating Machinery*

ASTM–D1868–81 *Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems*

Partial Discharge Signal Generation, Transmission and Acquisition; Fruth, Gross, and Florkowski

C. Personnel Qualifications

Understand how to run software in the Windows environment.

Obey the regulations outlined by GE and the specific power plant regarding high voltage testing.

Possess an understanding of how partial discharge occurs.

D. Environmental Health and Safety

Lethal high voltage is present during the partial discharge testing. All personnel must obey the regulations outlined by GE and the specific power plant regarding high voltage safety. As always, use common sense, be aware of potential hazards, make sure your electrical connections are clean and solid, and allow sufficient clearances between components at high voltage and ground.

E. List of Required Materials

1. ICM System

- One laptop computer running with ICM Version 2.41 software with IEEE–488 interface.
- One ICM acquisition unit.
- One RPA2 preamplifier.
- GPIB interface cables for Spectrum Analyzer and the ICM.
- Coaxial cables (RG58U).
- On-Line Testing: 4 minimum (two 2-footers, one 6″, and one to get to the terminal box [usually 3′–10′ is fine]).
- One partial discharge calibrator, CAL 1B for RPA2.

2. Tools and Equipment

- ▶ Hand-held oscilloscope (only for first time tests and troubleshooting).
- ▶ Coax cables as needed to connect the sensors with the data acquisition system.
- ▶ One RS232 cable for serial interface to ICM conpact (where applicable).

F. Set-Up Procedure

1. On-line Test Condition (with permanent installation)

   a. Locate the termination box.

   b. Connect an RPA between the ICM and the termination box. If a coaxial cable is used, keep as short as possible (no more than 10 feet, and preferably less than 3 feet).

   c. Synchronization with the 120VAC line is easiest and is provided by the ICM system.

   d. If a neutral coupler is present, the connection and data analysis is the same.

2. ICM Hardware Connections of Computer to ICM

   a. Connect the laptop computer to ICM amplifier unit via the GPIB interface and turn on ICM unit.

   b. Power up the laptop and run the PDA software.

   c. Connect the 15′(max) RG58 coax from CT to the input of RPA. NOTE: the connection is directional. Also, it is preferable to have the RPA as close to the CT as possible.

   d. Connect RG58 coax from output of RPA to ICM amplifier input (amp in).

   e. Connect the oscilloscope (if being used) to both the output of the RPA and the main amplifier. Set the scope on AC-decoupled and monitor both channels simultaneously.

   f. Repeat for each phase and neutral.

G. Calibration

1. Hardware Setup and Checkout

NOTE

PDA sensor calibration is simply an end-to-end equipment checkout of operability.

   a. Connect PD calibrator output to the HV terminal of the PD sensor. Connect the other end of the calibrator to a suitable ground.

   b. The phase being tested can NOT be grounded during the calibration procedure. If the phase cannot be ungrounded, then remove the connection between the PD sensor and the phase being tested.

NOTE

All applicable high voltage safety precautions must be continuously observed while working in the high voltage regions of a generator.

c. Turn on the calibrator to a suitable value (e.g., +5,000pC = 5nC).

d. Adjust the amplifier gain so that the red strip chart on the screen is in the center of the range (50%–75%).

e. Follow instructions as outlined in the “Software Operation” section.

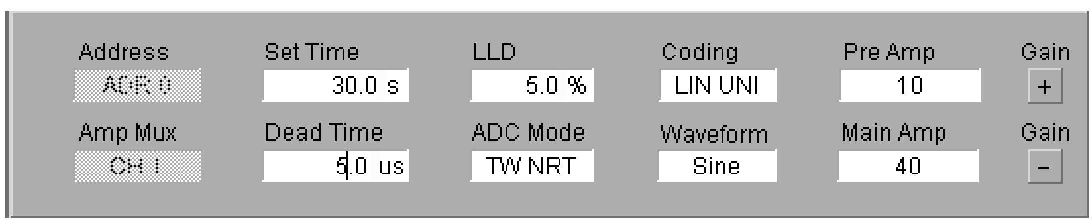
f. Repeat for the all the sensors.

2. Calibration – Software Operation

a. Click on SEARCH ICM (if ICM and laptop not communicating) and make sure they are communicating. All “LP” and “OK” lights (of interest) on the ICM should be lit and green.

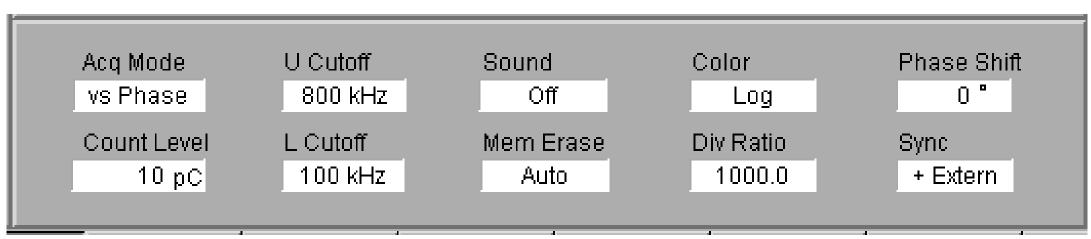
b. Make sure the “Report Header” is on (Options menu > “Report Header ON”).

c. Click “Setup A” and set the following:



- For RPA1 use “LIN UNI” coding. For RPA2 use “LIN BI” coding
- Adjust the gain up/down +/- to a suitable level.

d. Click “Setup B” and set the following:



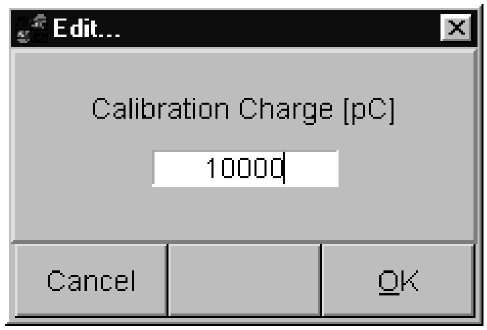
- The divider ratio is only important if you use an external probe (usually for synchronization).
- Set to Synchronize “Externally” and the calibration pulse will produce a nice line. If not, you only get a “dot” on the screen and it’s difficult to see.

e. Click “Setup G” and make sure the gating is OFF. It should not be necessary.

f. Adjust the gain to set the red strip chart to 50–75% full scale.

g. Click on the START button.

h. A line should appear on the screen. If not (you are synched), look for a point. Double-click on the line (or point) and a calibration window pops up for that location on the screen.



i. Enter the value the calibrator is set for (in this case, +10nC = 10,000pC).

j. Save the calibration file (call it: CalA.dat).

k. Now inject a pulse into each of the remaining sensors and verify that they produce roughly (within 10%) the same magnitude.

H. ICM Data Collection

1. On-Line data collection

a. Reload the appropriate calibration file (or a file from a previous test for this machine). If testing a previously tested machine, then retake patterns using identical conditions (esp. gain setting, RPA2, gating, etc.).

b. Click on Setup A, then Setup B, and then Setup G and verify your parameters are set as desired.

c. Click HOME.

d. Adjust gain for strip chart at 50–75%. ALWAYS start with the lowest gain and work your way up.

e. Click START.

f. It's a good idea to monitor signals at the pre-amplifier and the main-amplifier with an oscilloscope (set to AC-decoupled, 5 microsec per division, ~500 mV/div) to check for saturation conditions. Alternatively, you can simply change the gain setting (lower) and/or the ADC mode (from TW–NRT to FP–NRT) and vice versa. If pattern changes, choose the one that makes the most sense (physically).

g. Adjust trigger mode, and discriminator level to remove background noise and repeat measurement as necessary until you are satisfied you have obtained the best possible pattern.

h. Store results as a file with an intelligent name (P1G1R2A.dat, for example means Phase1, Gain1, using RPA2, file A (it's common to use file "G" for gated patterns)). Be sure the Report-Header is turned ON. After you press "SAVE", be sure to fill in the Comment field in the Report header (Phase, test voltage, CIV, gain, RAP [1 or 2?], noise-gating used (if any), test condition, etc.).

i. Record notes on data sheet.

j. If there is a neutral coupler, repeat the above for that as well.

If additional instructions are needed see the ICM User's Manual for complete details on operation of the ICM PC software program

V. SYSTEM MAINTENANCE

A. Maintenance Requirements

There are no special maintenance requirements for the PDA sensors. However, in order to minimize the risk of grounds from occurring the PDA couplers should be visually inspected during any regular planned outage and thoroughly cleaned of any surface contamination (dirt, dust, oil, etc.).

The ICM PC laptop (if provided) should be stored and maintained in accordance with industry good practice for such equipment.

B. PDA Sensor Specifications

The GE PDA sensor has been designed for collecting Partial Discharge (PD) signatures from high voltage rotating machinery. The sensor meets all material specifications of the IEEE/ANSI standards (corrosion, track-resistance, flashover, thermal-ratings, etc). The sensor allows for easy installation very close to the machine terminals thereby improving signal strength and the signal to noise ratio.

1. Specifications

Physical Dimensions:	10.5″ × 4″ × 4″
AC Rating:	27 kV AC
Hipot Rating:	3E+1 for 1 minute
BIL (Lightning Strike) Rating:	165 kV (6E+6)
Thermal Rating:	105°C
Capacitance:	1 nF
Signal Source:	HFCT
Frequency Range:	40 kHz–150 MHz
Operation:	Continuous availability of periodic on-line PD measurements

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