Experimental Comparison and Study on the Performance of Pulse Thyristor and Gate-turn-off Thyristor for Pulsed Power Applications

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EAPPC 2010 / BEAMS 2010
3rd Euro-Asian Pulsed Power Conference
18th International Conference on High-Power Particle Beams
October 10–14, 2010 / ICC Jeju, Jeju, Korea

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Pulse Thyristors

✓ **Pretty high current and d*i*/d*t* rating (>10 kA/*μ*s)**

✖ **High price**

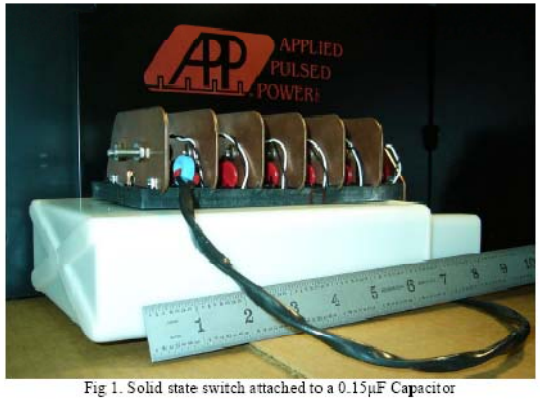


Fig 1. Solid state switch attached to a 0.15μF Capacitor

Gate-turn-off Thyristor (GTO)

✓ **Relatively low price**

✖ **Low turn-on speed and thus low d*i*/d*t* rating**

Preliminary Test of the Turn-on Behavior of GTO and Pulse Thyristor

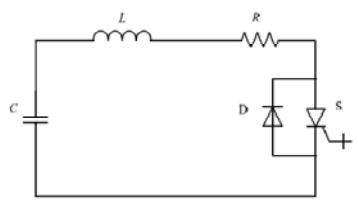


Figure 1. Preliminary test circuit of the thyristors.

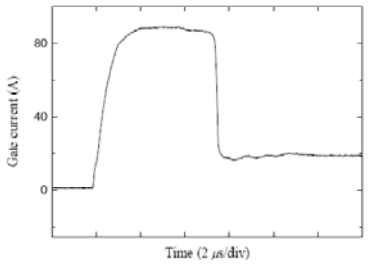
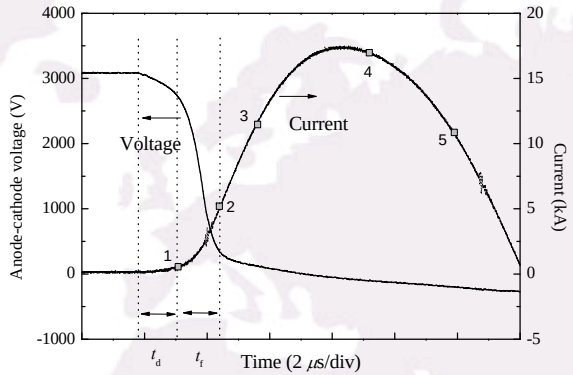


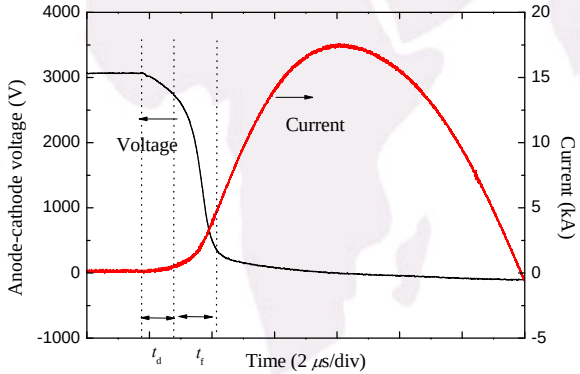
Figure 2. Gate drive current waveforms of the thyristors

TABLE I. THE MANUFACTURE'S SPECIFICATIONS FOR THE GTO AND PULSE THYRISTOR

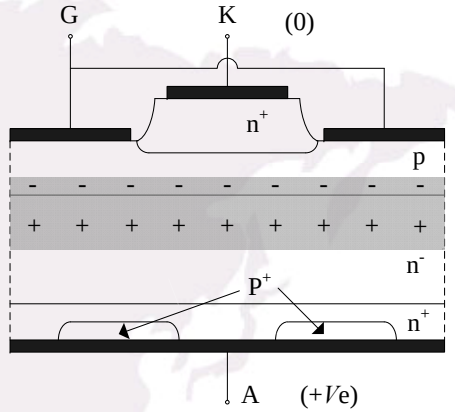
Characteristic	KGB3000-45	PT85QWH45	Unit
Repetitve peak off-state voltage	4500	4500	V
Peak turn-off current	3000	N/A	A
R.M.S on-state current	1460	1225	A
Non-repetitive surge on-state current	24	29.6	kA
Critical rate of on-state rise	800	22000	A/μs



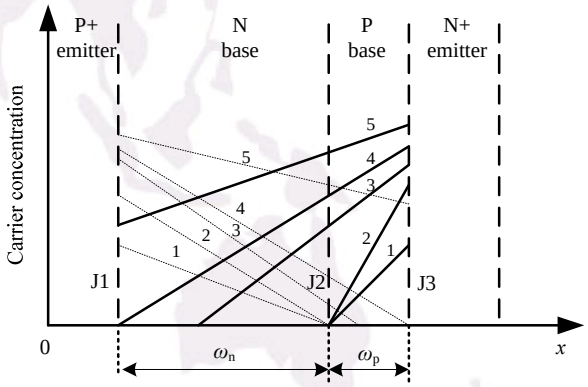
(1) GTO



(2) Pulse thyristor



(3) Single island of GTO



(4) Evolution of carriers in the turn-on process

Use Magnetic Assist to Minimize Switch Loss

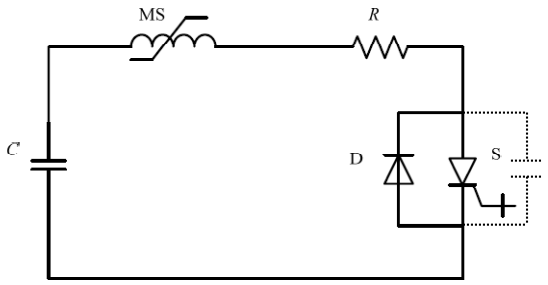
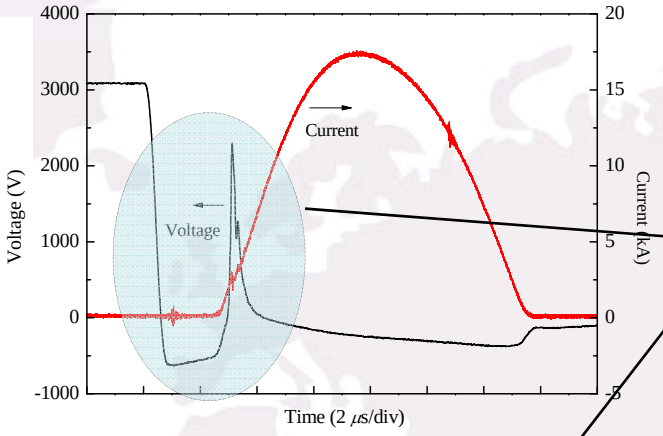


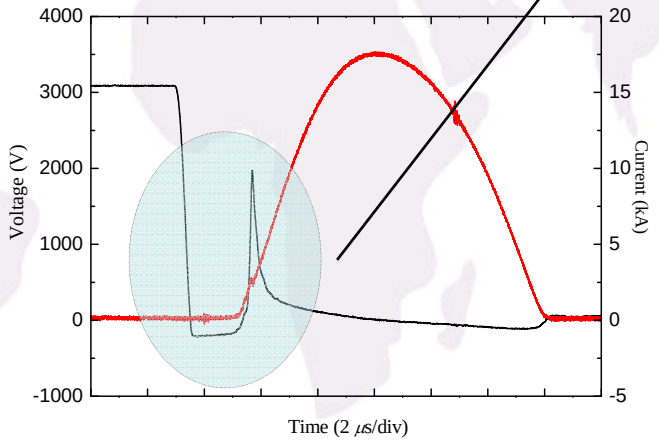
Figure 6. Test circuit of the thyristor, with the magnetic assist switch MS.

Tabel 2. Parameters of the Magnetic Swtich

Material	Nanocrystalline alloy (1K107)
Initial relative permeability	13.9k
Saturated relative permeability	1
Physical Size	120 (OD)×60 (ID) ×240 (H)
Volt-second product	7500 V·μs
Delay time	2.5 μs



(1) GTO



(2) Pulse thyristor

Negative voltage and spike ?

Caused by parasitic capacitance and slow plasma spreading velocity

Is the analysis right? How to verify?

PSpice Simulation Model of GTO

Different current distribution in each island-ring of the GTO. Caused by drive signal transfer delay

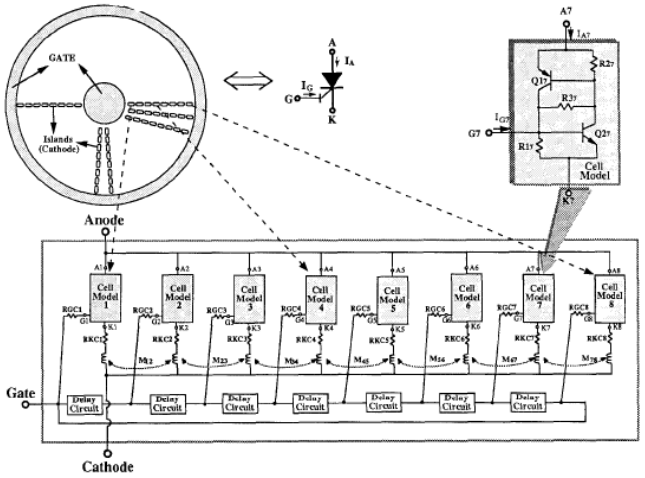
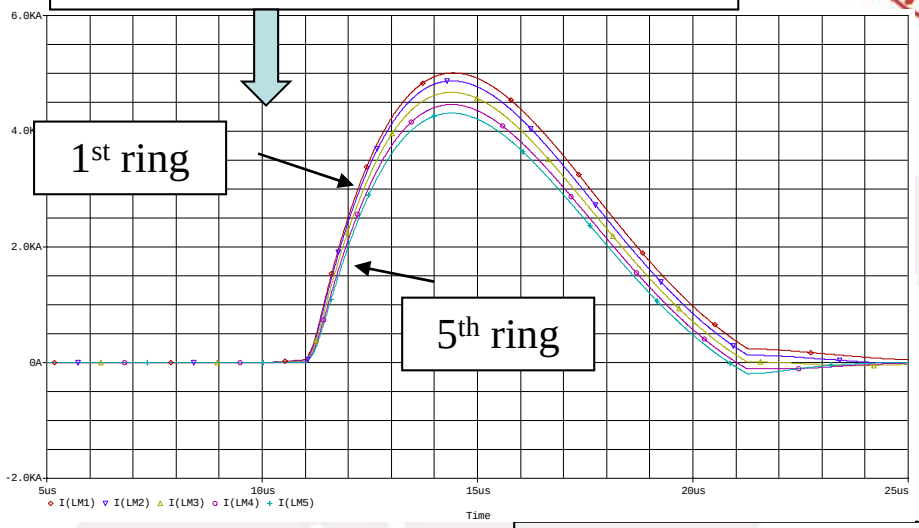
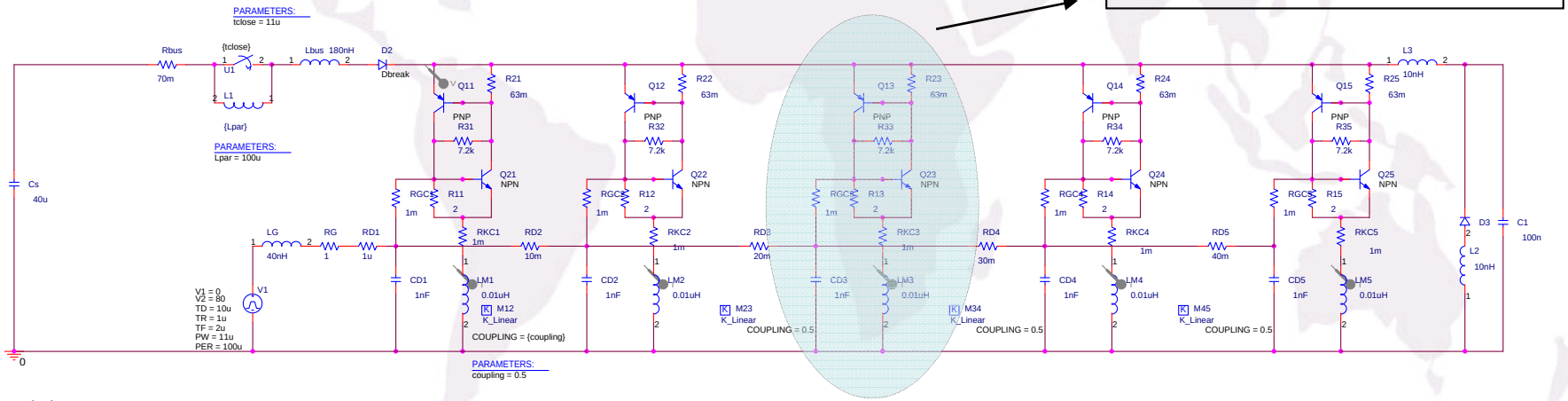


Fig. 5: GTO multi-cell circuit model containing 8 cells to simulate the lateral distributed 8-rings GTO device



One island-ring of the GTO



Tsay, C. L., R. Fischl, J. Schwartzenberg, H. Kan, and J. Barrow, "A high power circuit model for the gate turn off thyristor," *Digists 21st IEEE Power Electronics Specialists Conference*, 1990

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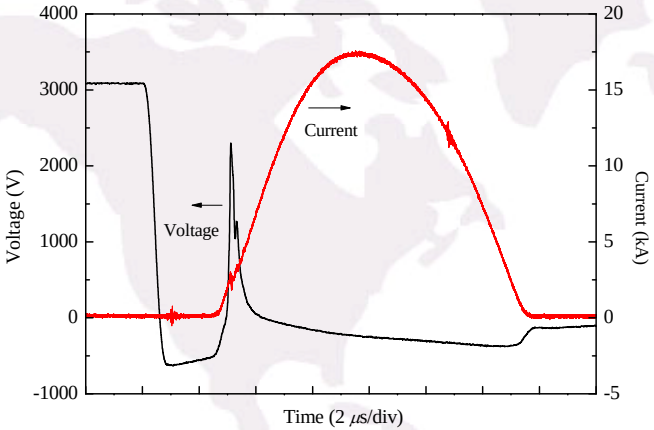
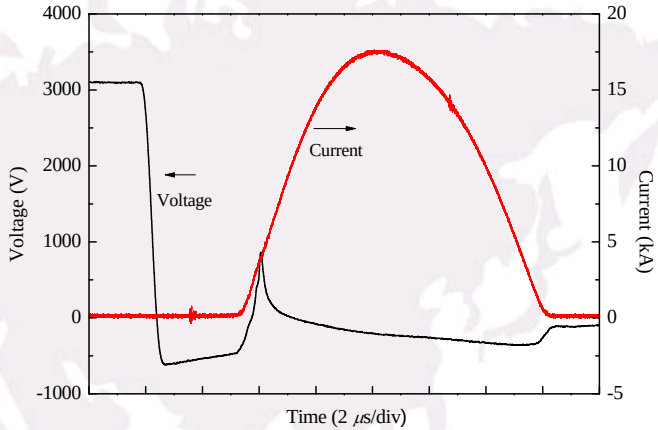
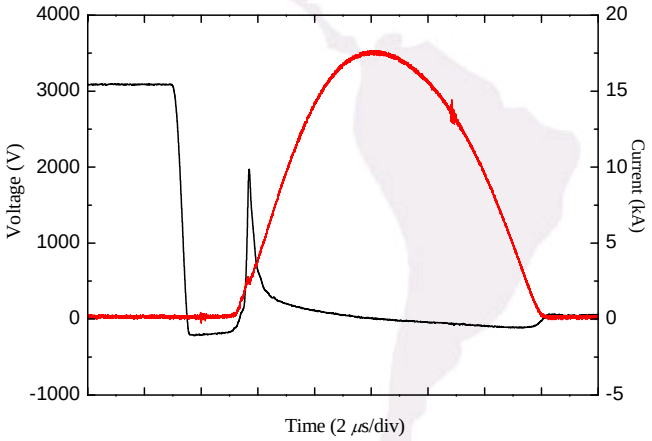
Measure to Lower the Voltage Spike (1)

Prolong the delay time of the magnetic assist

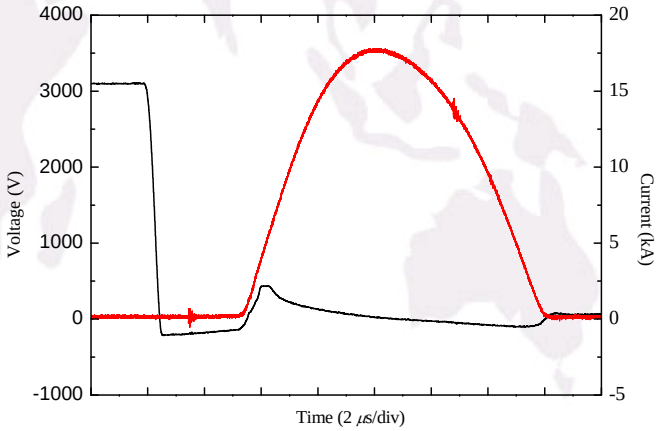


GTO





Pulse thyristor



Measure to Lower the Voltage Spike (2)

Add a series-connected *R*-*C* circuit in parallel with the thyristor

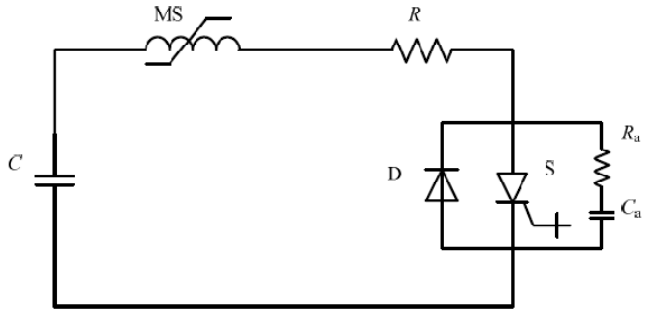
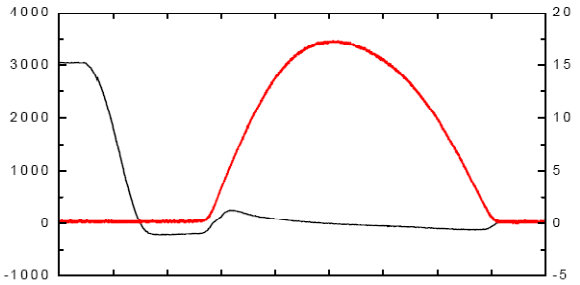


Figure 11. Test circuit of the thyristors, with the *R*-*C* circuit for voltage spike absorption.

GTO



(a)

Pulse thyristor

Tabel 3. Test Results of the GTO

Peak current	17.3 kA
Current rise time	4.8 μs
Average d*i*/d*t* value	3.6 kA/ μs
Maximum d*i*/d*t* value	6 kA/ μs
Turn-on Loss	＜0.5 J
Delay time	2.5 μs

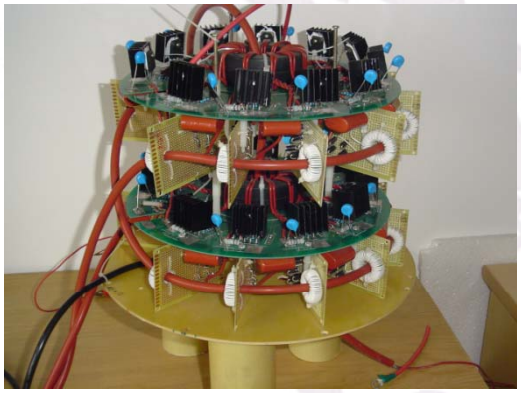
and
ased
magnetic time delay and R-C absorption circuit. Vertical axis unit: Volt (left), Kiloampere (right); horizental axis scale: 2 μs per div.

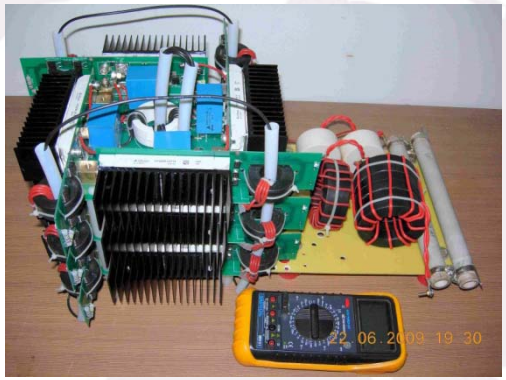
The discharging current of capacitor C_a
provides a small current flowing through GTO
and accelerates spreading of turn-on area inside the GTO

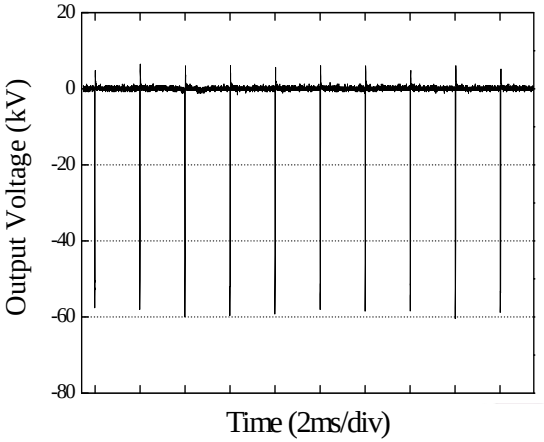
Conclusion

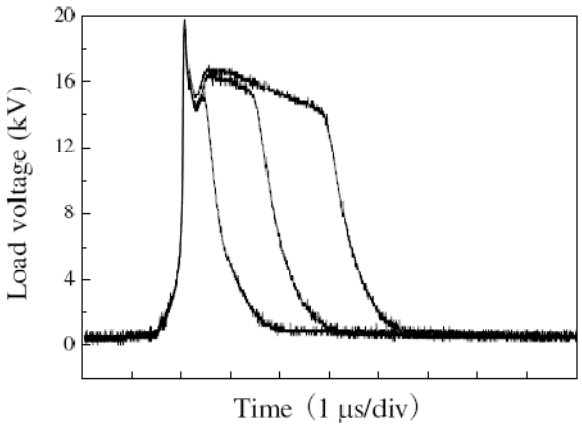
(1) GTO exhibits excellent pulse operation abilities.
(2) The time delay effect of the series-connected magnetic switch results in the anode-cathode voltage spike when large current rises steeply.
(3) By increasing magnetic assist time and providing a small current flowing through the GTO before large current appears, the amplitude of the voltage spike has been greatly reduced.
(4) The power dissipation associated with switching process is minified and GTO's safe operation is guaranteed.
(5) The design will permit construction of compact, light-weight serial switch strings required for high-voltage pulsed power sources to substitute for expensive pulse thyrsitors.

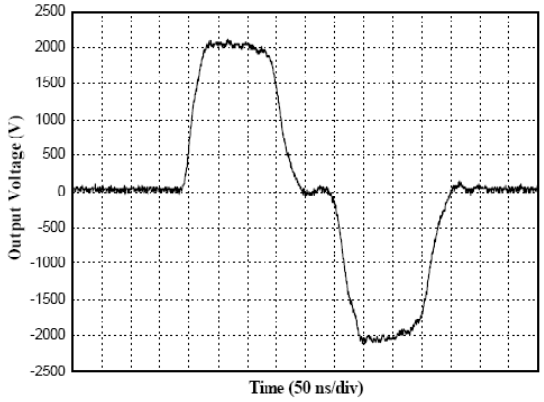
Our Research Group Focuses on All Solid-State Pulsed Power Sources











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Thank you!