30 to 100mA Directly Tripping GFCI Transformers for Sinusoidal ac Currents, Type AC.

GFCI's designed to trip at 30mA, do not allow the victim of an electrical shock to let go at current levels between 5mA and the trip level. They do protect against heart fibrillation. At current levels between 5 - 30mA the victim might experience extreme discomfort for a short time until his body resistance decreases to allow a current flow to go to the 30mA trip level.

Devices operating at 20 - 30 fault current, do not require electronic amplification for the tripping of the circuit breaker. They extract from the primary circuit at the current level of 30mA sufficient power to trip a precision relay requiring 120μVA to 200μVA. The power transformer for a core having a cross section of Ac (cm^2) and ℓm (cm) path length and a permeability μ at a fault current iF can be calculated by:

$$VA = 1.26\ Ac\ f\ np^2\ iF^2\ \mu/\ell m \cdot 10^{-8}$$

In general, cores with a cross section of about $1cm^2$ and a mean path length of 6cm are chosen made of .1mm thick Supermalloy, which at 3000 Gauss, has a permeability exceeding 250,000.[7] The thin tape of .1mm is necessary to minimize the core losses. Normally 3 to 6 primary turns are used. In Fig. 10 is shown the permeability of a typical core after various heat treatments. The designer should be aware that cores which are typically heat treated at 1150°C in a hydrogen atmosphere and then either fast cooled or stabilized for 1 hour at 400°C to 500°C have different properties. Cores stabilized at 400°C for high temperature stability to -20°C have a lower permeability after a low resistance fault at + 60°C, than cores which are stabilized at a higher temperature (485°C), for good stability to only -5°C. It is therefore necessary to specify the core parameters properly.

Circuit breakers with these transformer cores interrupt the electrical supply current reliably under ac conditions. They do not trip in SCR controlled power lines which supply only unidirectional halfwaves.

20 - 30mA GFCI Transformer Cores for Pulsed Unidirectional and ac Currents.

The previously described GFCI's will not trip reliably or at all, when used in SCR controlled electrical power supply circuits, in which for instance, only unidirectional ac currents flow, because the current sensing core would then operate only between remanence and the flux density to which the core can be magnetized by the primary fault current x turn product.

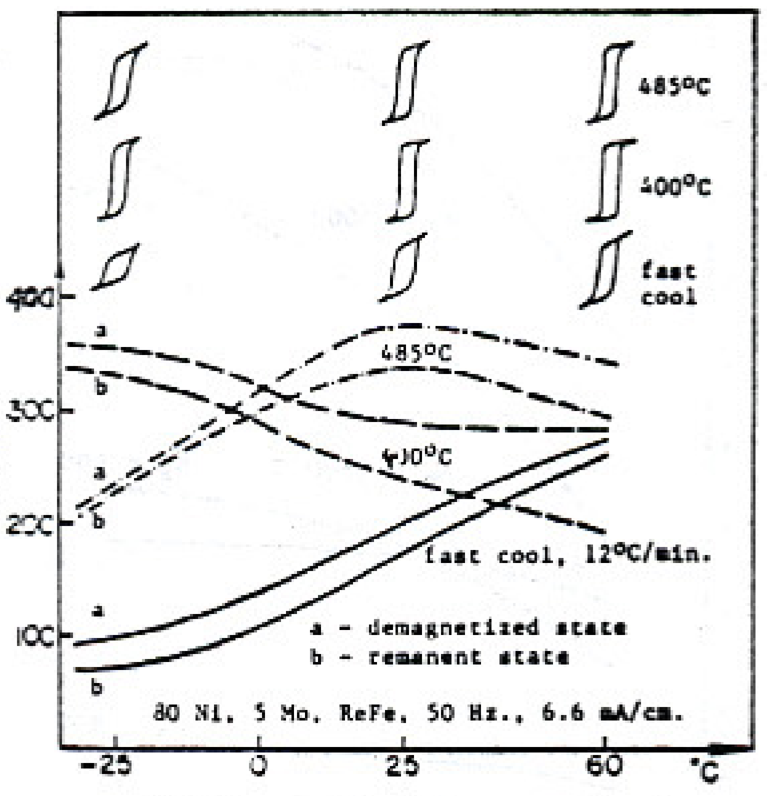

Fig. 10 - Permeability and hysteresis loop of Supermalloy at 6.6 mA/cm in the demagnetized and remanent state of magnetization after various heat treatments.

Roesch and Schwartz[8-9] proposed to form a resonance circuit by connecting the secondary turns of the sensing transformer to a capacitor to create a resonant circuit. Usually a resonance frequency of twice the sinusoidal frequency is chosen. The core will then extract sufficient power from the primary current at one way rectified currents as well as under two way rectified currents or 135° phase cut unidirectional currents, which are equivalent to a much shorter pulse. IEC document 23E allows for pulsating dc currents 1.4 times higher currents than for true ac currents. Fig. 11 shows the tripping requirements per IEC document 23E.

Tripping time should be kept below 200ms (12 cycles at 60Hz) at the rated current and below 100ms (5 cycles) at twice the rated value. The IEC document proposes longer trip times of 500ms for .03A devices and even 40ms for 250mA currents.

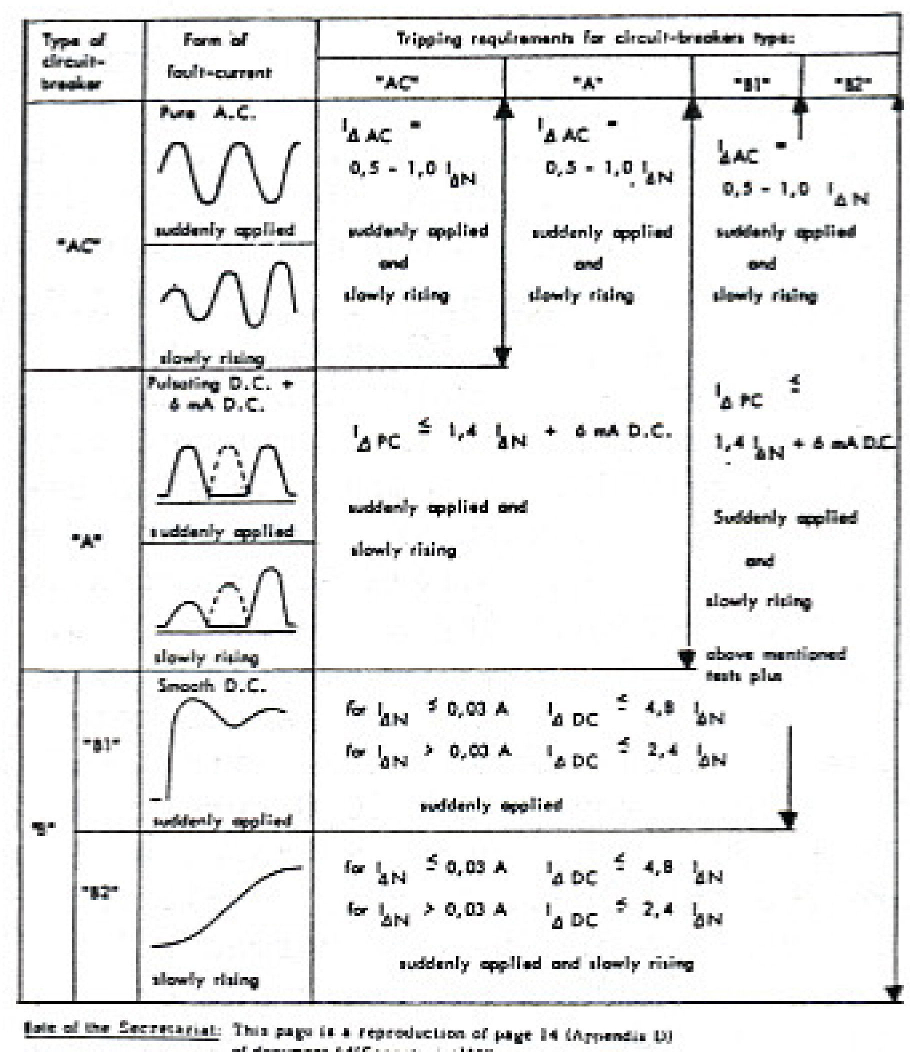

Fig. 11 - Tripping requirements for circuit breaker per IEC document 23E.