ADVANCE IN SHORT- CIRCUIT CO - ORDINATION OF CONTACTOR AND MOTOR STARTERS WITH FUSES.

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1 General.

A document is still under study at international level (IEC-SC32B) dealing with guidance notes on co-ordination between fuses and contactors/motor-starters. The work is carried out by IEC fuse experts in collaboration with contactors/starters manufacturers and is based on the results of researches and type testing throughout the world. The test requirements for the co-ordination between contactors or motor starters and fuses are specified in IEC Standards 947-4-1.

Experience has shown that the knowledge of the principles leading to the Standards requirements is useful to people which are bound to comply with them. The guidance notes under consideration, then, should provide guidance to assist both the manufacturers and the users in selecting the most suitable fuse-link ensuring co-ordination with a properly specified contactor/motor starter. As well known, the criterion for co-ordination is based on the comparison of the I^2t and peak current withstand of the contactor and its relay with the total I^2t and cut-off characteristic of fuses.

The comparison has to be made in accordance with the test results expected with reference to the standardized types "1" or "2" of co-ordination. An additional type "3" of co-ordination, which has been recently proposed by USA IEC Committee to cover continuity of service after the occurrence of specified overcurrents is deemed very interesting.

According to type "3" co-ordination, no damage to the overload relay or other parts and no welding of contactor or starter contacts are permitted.

Fuse-links suitable for ensuring required values of total I^2t and peak current are easy to be found, as, usually, the corresponding characteristics are clearly specified in agreement with the IEC Standards by fuse manufacturers. As regards contactors or starters, their effective withstand characteristics to I^2t or peak current values are ordinarily not specified. It is customary to state only that a given contactor or starter protected against overcurrents by fuses or other SCPD's complies with the test requirements of a standardized type of co-ordination. The specification of the thermal and electrodynamic characteristics of a given contactor or starter under short-circuit conditions seems therefore to be worthy of further discussion.

A contribution is presented in this paper together with the results of an appropriate experimental research. The withstand characteristics of a specified contactor protected by fuses are shown, as an example, and the conditions are discussed to meet in turn the requirements of types "1" and "2" of co-ordination and, in addition, those of the above mentioned type "3". The experimental results are referred to prospective short-circuit current values up to 50 kA (r.m.s. value).

2 Dependence of I^2t withstand of a contactor upon the electrodynamic contact repulsion.

Whenever I^2t withstand of a contactor is examined, it is necessary to state the prospective current value to which reference is made. In fact the I^2t withstand of a contactor protected by a given fuse strictly depends upon the current flowing through the contactor, so that the I^2t values as a function of the prospective current vary like those shown in figure 1.

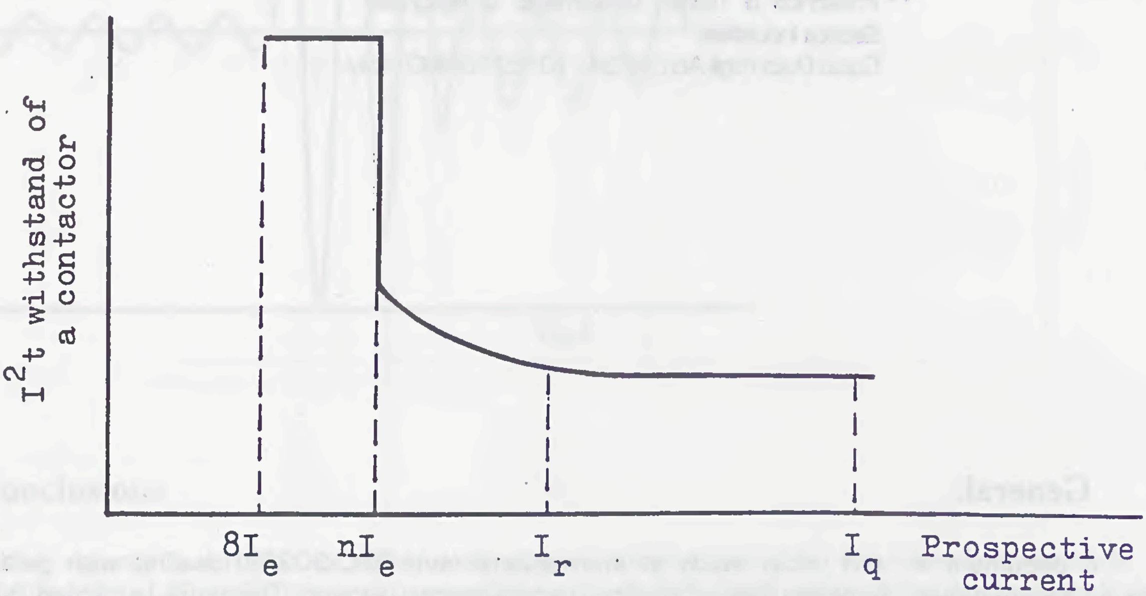

Fig. 1 I^2t withstand of a contactor as a function of prospective current through its contacts

- I_e Operational current for utilization category AC3 of the contactor
- $8\,I_e$ Overload withstand capability (for 10 s) of the contactor
- $n\,I_e$ Minimum current value for which separation of contacts of the contactor (by electrodynamic effect) occurs
- I_r IEC test current related to the operational current for utilization category AC3 of the contactor
- I_q Rated conditional short-circuit current.

It can be seen from figure 1 that the I^2t withstand of a contactor rapidly decreases starting from the current value for which the contacts of the contactor are just thrown apart by electrodynamic effect.

The importance of such a current value has been discussed in previous papers; here the results are reported of some appropriate experimental tests intended to emphasize its influence on the I^2t withstand value of a contactor.

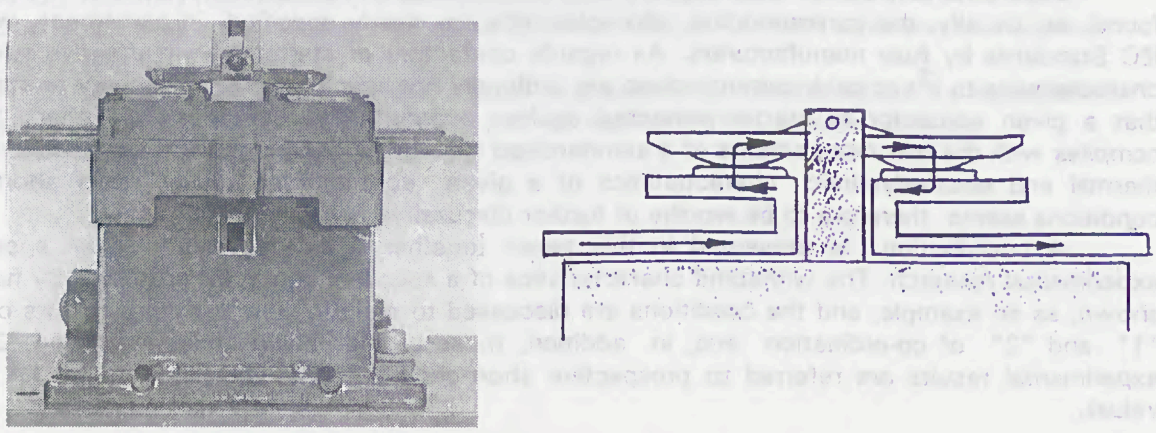

Fig. 2 Photograph a) and relevant sketch b) of the contactor tested.

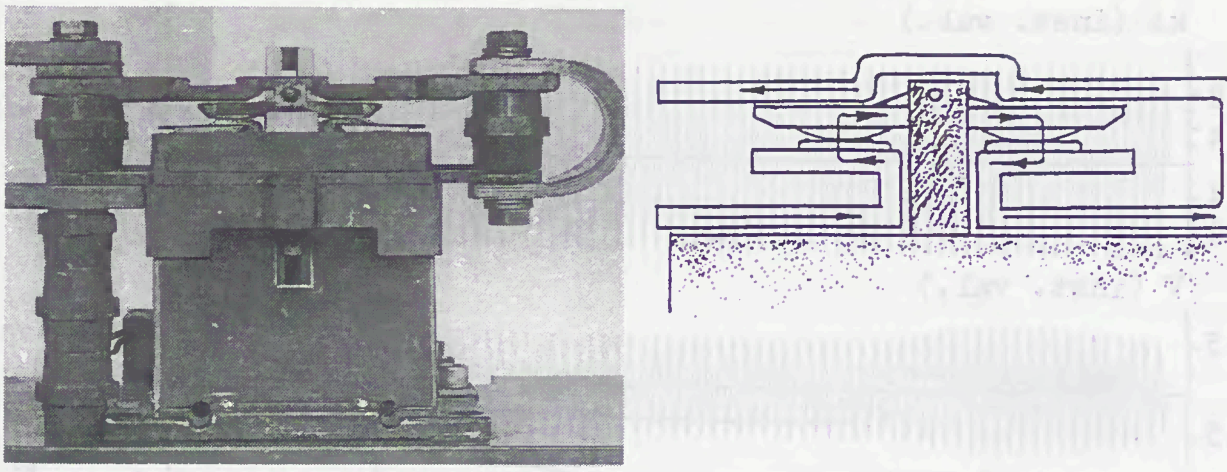

Fig. 3 Photograph a) and relevant sketch b) of the artifice by which the I^2t witstand of the contactor shown in fig.2 has been increased.

The tests were carried out at a convenient voltage, 50 Hz, on a single pole of a contactor (shown in figures 2 a), b)) having a rated operational current, I_e, of 300 A.

According to IEC Standards, this contactor has an overload withstand capability of $8I_e$ (2400A, r.m.s.) for 10 s, i.e. an overcurrent withstand I^2t of about $58 \cdot 10^6$ A^2s.

The pole of the contactor was submitted in the closed position to successive tests in order to check its adequacy to withstand the above value of I^2t ($58 \cdot 10^6$ A^2s) with increased current values. The current was therefore gradually raised test by test and its duration correspondingly decreased so as to maintain constant the I^2t let-through value.

The test results confirmed that for current values higher than $8I_e$, but lower than that which starts separating the contacts by electrodynamic effect, i.e. up to 4000 A, r.m.s. value, (about 5700 A peak value) no contact damage occurred. In other words, the I^2t withstand value relevant to the overload capability of the contactor remained unaltered up to the current value (about 13 I_e) for which electrodynamic separation of the contacts occurred.

By the artifice shown in figures 3 a), b), to be compared with figures 2 a), b), the current value causing contact separation by electrodynamic effect of the poles of the contactor was then increased up to $26I_e$ (7,8 kA r.m.s.,11 kA peak value).

The corrisponding diagram of the I^2t withstand becomes that of figure 4.

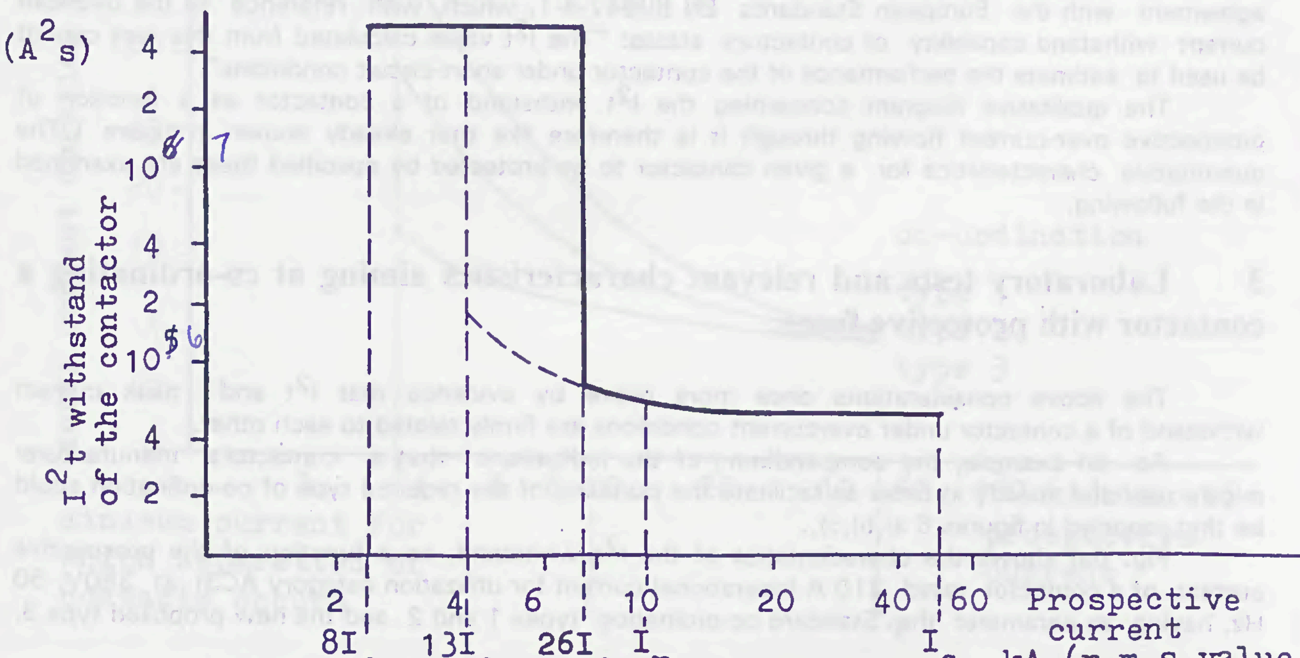

Fig. 4 I^2t withstand of the contactor, arranged as shown in fig. 3 a), b), as a function of prospective current through its contacts.

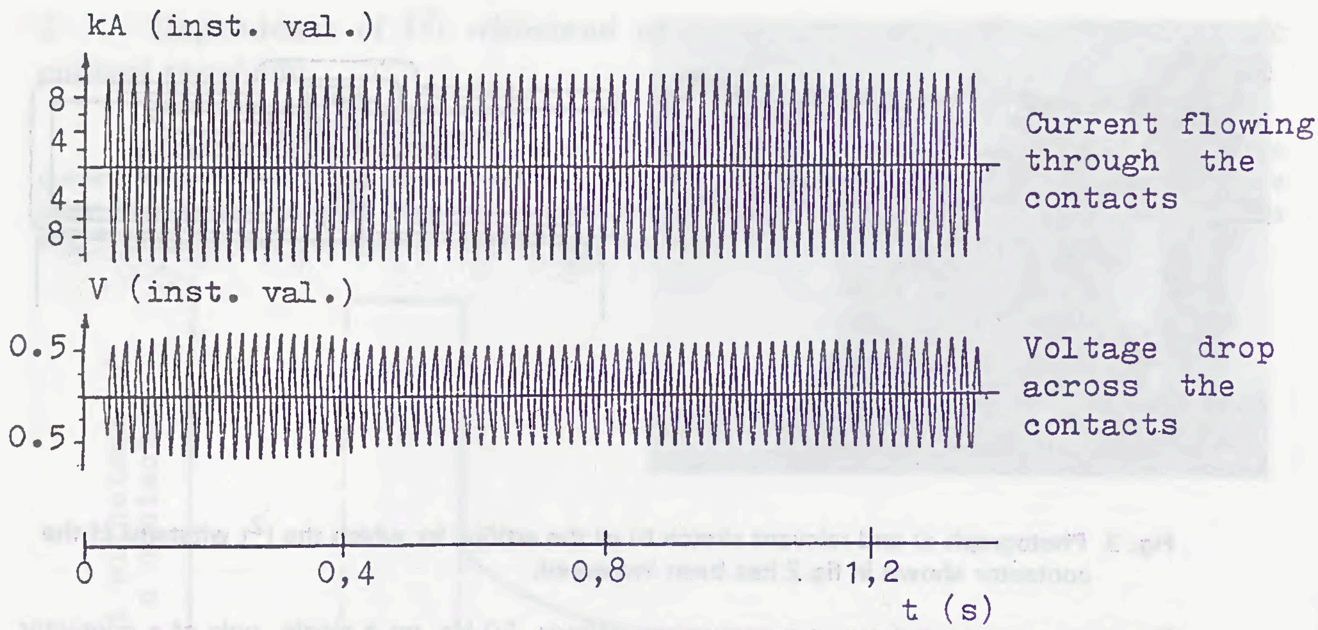

Fig. 5 Oscillogram of the test current (25 I_e) withstood for 1.35 s without any damage by the contactor shown in fig.3

In fact, in the operating conditions of fig.3, the conclusive test was carried out with a current value of 7,5 kA (25 I_e) for the duration of 1,35 s, without causing any kind of damage to the pole contacts of the contactor.The related test oscillogram is shown in fig. 5.

The corresponding I^2t withstand of the contactor resulted ($76 \cdot 10^6$ A^2s) , i.e. 35% more than its overload I^2t withstand.

A further increase of the test current above 7,5 kA caused the expected phenomenon of contact separation which, as well known, is regularly accompanied by arcing, contact erosion or welding and serious damage to other parts of the contactor.

It is evident, again, that the I^2t withstand of a contactor is limited by the current value for which its contacts are thrown apart by electrodynamic effect.

Laboratoty experience shows that the I^2t withstand of a contactor for currents higher than that causing contact separation becomes much lower in comparison with that corresponding to its overload capability and has to be limited by a suitable fuse-link (or other SCPD).This is in agreement with the European Standards EN 60947-4-1, which, with reference to the overload current withstand capability of contactors, states: "The I^2t value calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions".

The qualitative diagram concerning the I^2t withstand of a contactor as a function of prospective over-current flowing through it is therefore like that already shown in figure 1.The quantitative characteristics for a given contactor to be protected by specified fuses are examined in the following.

3 Laboratory tests and relevant characteristics aiming at co-ordinating a contactor with protective fuses.

The above considerations once more prove by evidence that I^2t and peak current withstand of a contactor under overcurrent conditions are firmly related to each other.

As an example, the compendium of the indications that a contactors manufacturer migth usefully specify in order to facilitate the pursuing of the required type of co-ordination could be that reported in figures 6 a),b),c),.

Fig. 6a) shows the characteristics of the I^2t whitstand, as a function of the prospective current, of a contactor rated 210 A (operational current for utilization category AC3) at 380V, 50 Hz, having as parameter the Standard co-ordination types 1 and 2 and the new proposed type 3.

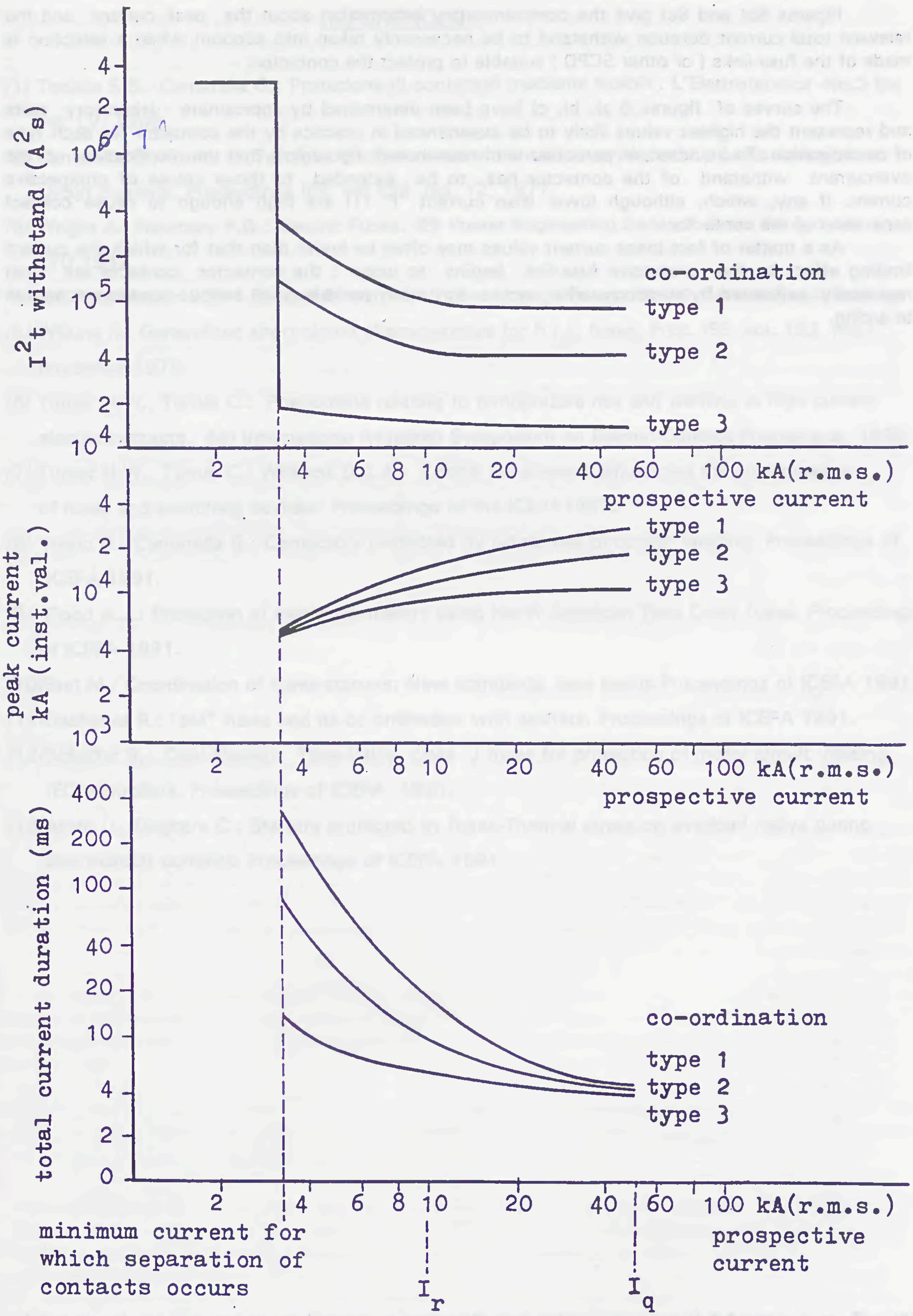

Fig. 6 I^2t **withstand a), peak current b) and current duration c) of a contactor rated 210 A (AC3), 380 V, 50 Hz, as functions of the prospective current, for the three standard types of co-ordination.**

Figures 6b) and 6c) give the complementary information about the peak current and the relevant total current duration withstand to be necessarily taken into account when a selection is made of the fuse-links (or other SCPD) suitable to protect the contactor.

The curves of figures 6 a), b), c) have been determined by appropriate laboratory tests and represent the highest values likely to be experienced in practice by the contactor for each type of co-ordination. To be noted, in particular with reference to figure 6c) ,that the verification of the overcurrent withstand of the contactor has to be extended to those values of prospective current, if any, which, although lower than current "r" (1) are high enough to cause contact separation of the contactor.

As a matter of fact these current values may often be lower than that for which the current limiting effect by the protective fuse-link begins to occur : the contactor contacts are then repeatedly separated by electrodynamic stress for many periods, with serious consequences due to arcing.

(1) .- Test current "r" is a current related at discrete steps to the rated operational current for utilization category AC3 of the contactor. The current "r" values are specified in the above quoted International Standards.

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