# OVERLOAD PROTECTION OF CONTACTORS BY FUSES

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## I. GENERAL

The protection of contactors against overcurrent by fuses has been the object of many studies particulary as regards the requirements for satisfactory co-ordination between contactors and fuses under short-circuit conditions.

Fuses to be used to protect modern contactors against short-circuit currents can easily be chosen today on the basis of the International Electrotechnical Standard prescriptions. Moreover, comprehensive papers can be found in the technical literature concerning the performance results of the different types of contactor-fuses co-ordination ( * ).

Additional information can also be found about the fuse ratings which can satisfactorily reduce the risk of contact welding under short-circuit conditions.

Nevertheless further work is still needed, in our opinion, to provide criteria for assisting in the selection of fuses suitable for overload protection of contactors.

## II. SCOPE

Scope of the present paper is to contribute to the solution of the above problem by discussing the possibility of utilizing for the contactor overload protection the same fuse previously selected for the contactor short-circuit protection.

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( * ) Some Standard requirements relevant to the present paper are here recalled :
Type 1 co-ordination: damage to the contactors is acceptable. There has been non discharge of parts beyond the enclosure, nor damage to the conductors or terminals.
Type 2 co-ordination: no damage is occurred, except that welding of contactor contacts is permitted, if they are easily separated.

In the following, reference is made to those fuses which proved to be capable to prevent contactors from contact welding under short-circuit conditions.

The background to above considerations is the overload current withstand capability of contactors as specified in sub-clause 7.2.4.4 of European Standard EN 60947 - 4 - 1 ( corresponding to I EC Pubblication 947 - 4 - 1 ).

Accordingly, contactors with utilization categories AC - 3 or AC - 4 shall withstand the overload current for the duration as specified in the following table :

Table IX

| *Rated operational current* | *Test current* | *Duration of test* |
|---|---|---|
| ≤ 630 A | 8 x $I_e$ max AC 3 | 10 s |
| > 630 A | 6 x $I_e$ max AC 3 | 10 s |

In addition, a Note under Table IX clarifies that these specified overload current withstand requirements of contactors cover also duties where the current is less than that shown in the Table and its duration is longer than 10 s, provided that the related value of $I^2t$ is not exceeded.

Reasonably, the same $I^2t$ value can be assumed to be withstood by contactors for overcurrents higher than that shown in Table IX up to the current value at which the contacts of the contactors are just thrown apart by electrodynamic effect [ 7 ].

## III. EXAMPLE OF TEST PROCEDURE

As a consequence, the contactor overload withstand $I^2t$ characteristic plotted in a time - current diagram ( log - log ) becomes like that shown in fig.1, i.e. a right line extending from its conventional free - air thermal rated current, $I_{th}$, up to current value for which contact repulsion begins, $I_{rep}$.

In particular, the example of fig. 1 is referred to a contactor specified as follows :

$I_e$ = 100 A ( AC - 3 rated operational current, r.m.s. ).

$I_{th}$ = 180 A ( rated conventional free - air thermal current ).

$I_{rep}$ = 3300 A ( current value for which the contacts of contactor begin to be thrown apart by electrodynamic effect, r.m.s. ).

$I^2t$ = 6,4 $MA^2s$ ( constant $I^2t$ value corresponding to $(8\ I_e)^2 \cdot 10$ s, according to which the above right line is reported in figure 1 ).

In the same diagram of fig. 1 the time - current characteristics are also reported of the fuses previously chosen for the protection of the contactor against short - circuit currents .

As above said, these fuses rated 80, 100 and 125 A proved to be capable of preventing the contactor of 100 A from contact welding in an appropriate short-circuit research made in the past [ 7 ].

More generally the fuse parameters identified in that circumstance are recalled in the diagram of figure 2, together with other results of the tests made on 80 types of contactors of different ratings manufactured by different European manufacturers.

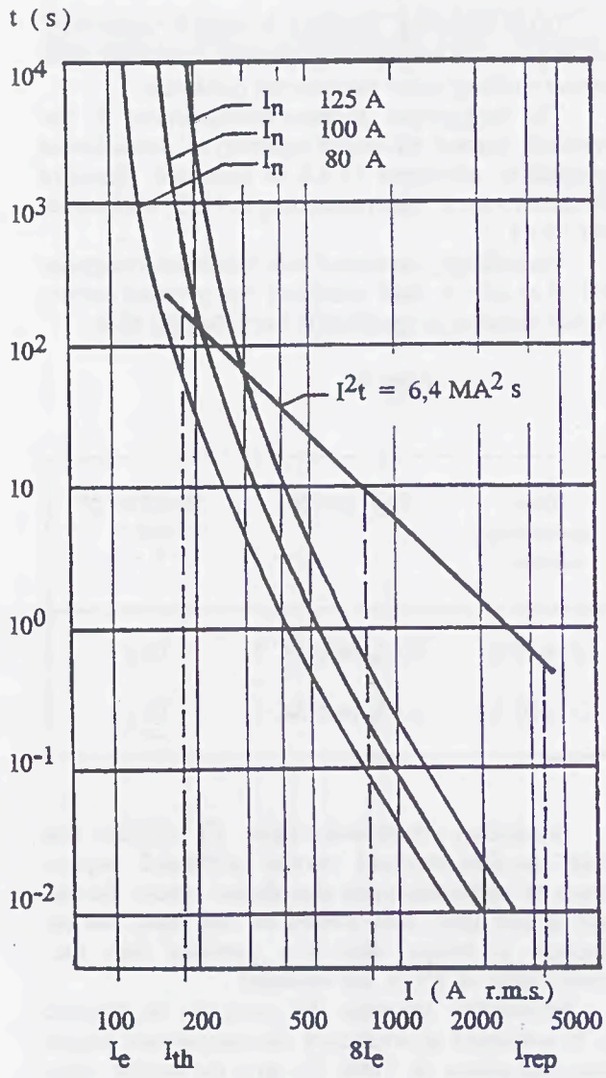



Fig.1

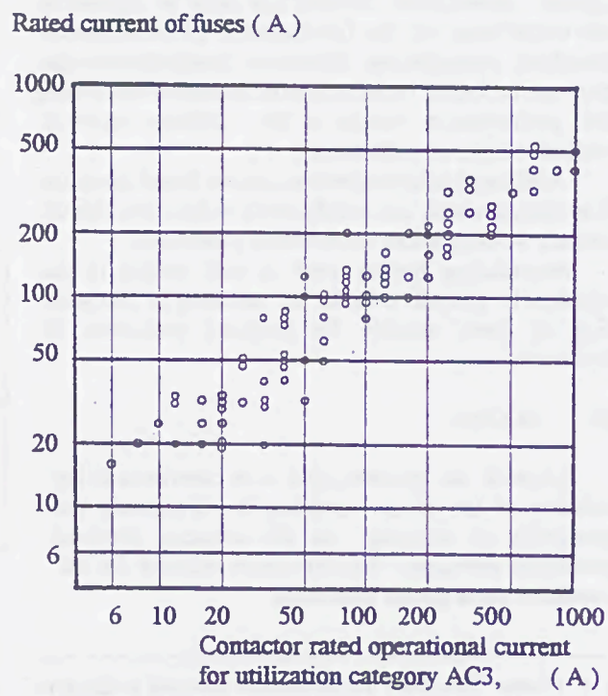



Fig.2

The diagram shows the maximum rating of fuses which prevented the tested contactors from contact welding under short - circuit conditions, as function of the rated operational current for utilization category AC - 3 of the contactors.

Coming back then to the example of fig. 1 let's begin to consider a gG fuse rated 100 A as the overload protective fuse. Its time - current characteristic crosses the contactor withstand time-current characteristic ( plotted as $I^2t$ constant value ) in the point 220 A - 120 s . It is obvious that only a region on the left side of this point has to be verified by appropriate tests as regards the temperature - rise overload performance on the contactor. It is included between the current limits 220 ÷ 180 A ( as 180 A is the contactor rated thermal current ).

That was done under the same test conditions as those specified for type tests and recalled in the following. The test results are summarized in the table below :

| *Test current (A r.m.s)* | *Current duration (s)* | *Temperature - rise of contacts (K)* | *Temperature - rise of contacts (K)* |
|---|---|---|---|
| 220 | 120 | 60 | 39 |
| 200 | 240 | 79 | 57 |
| 185 | 800 | 91 | 70 |

According to the values of the table it is proved that the fuse rated 100 A is suitable for the overload protection of the contactor, as in no case the temperature - rise of terminals exceeds the value of 70 K, which is admitted for continuous duty service.

The test results obtained then with a protective fuse rated 125 A, under unaltered remaining conditions, are :

| *Test current (A r.m.s)* | *Current duration (s)* | *Temperature - rise of contacts (K)* | *Temperature - rise of contacts (K)* |
|---|---|---|---|
| 300 | 70 | 62 | 38 |
| 230 | 300 | 105 | 83 |
| 200 | 3900 | 138 | 115 |

The data of this table clearly show that the ageing of the contactor insulation and of the cables connected to the contactor terminals become more important. It appears, as well, that overload currents of longer duration may determine the softening of PVC insulation. As well known, cables manufacturers highly recommend to avoid that. In favour of safety therefore, the fuse rated 100 A should be preferred for overload protection.

## IV. OTHER EXPERIMENTAL RESULTS.

By the same experimental procedure, the research was extended to other contactors chosen with rated current uniformly spaced, in a certain degree, in the range of contactors shown in abscissae of figure 2.

They are reported in the following table, together with the corresponding rated currents of the fuses capable to avoid contact welding under short - circuit conditions.

| *Contactor rated operational current ( A r.m.s. )* | *Protective fuse rated current ( gG ) ( A r.m.s. )* |
|---|---|
| 20 | 20 - 25 - 32 |
| 63 | 50 - 63 - 80 - 100 |
| 100 | 80 - 100 - 125 |
| 250 | 160 - 200 - 250 - 315 |
| 630 | 315 - 400 - 500 |

The final results of the tests carried out as above said, i.e. under the condition that the temperature-rise of 70 K of contactor terminals is never exceeded under overload conditions, are reported in the following table:

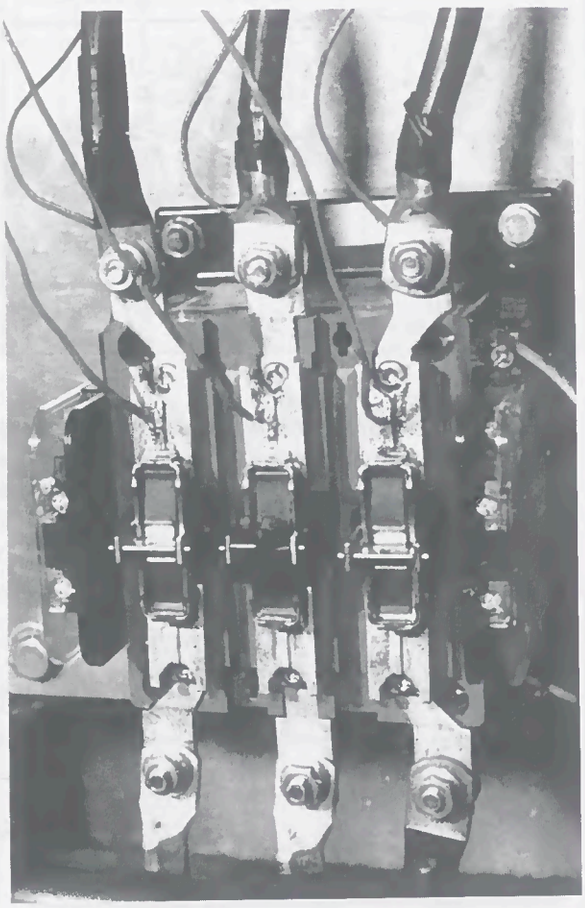
| *Contactor rated operational current ( A r.m.s. )* | *Protective fuse rated current ( gG ) ( A r.m.s. )* |
|---|---|
| 20 | 20 |
| 63 | 63 |
| 100 | 100 |
| 250 | 200 |
| 630 | 500 |

The time - current characteristics, corresponding to that of fig.1, on which test considerations were based, are shown in figures 3, 4, 5 and 6.

## V. TEST PROCEDURE SPECIFICATIONS

The tests were carried out in a single phase circuit supplied with alternating current at 50 Hz. The poles of each contactor were connected in series and the terminals were connected to the supply by PVC insulated copper cables having cross sectional areas in accordance with the Standard requirements for the temperature-rise tests.

Temperatures near the contacts and at the terminals of each contactor were measured by suitable thermocouples. Photograph F.1 shows one of the contactor under test, together with its supply connections and thermocouples positions.



F.1

## VI. CONCLUSIONS

A simple way is presented to achieve overload protection of contactors by fuses. As a basis for this protection the utilization is suggested of the fuses previously selected for the protection of the same contactors against short - circuit currents. In particular, reference is made in the present paper to those fuses which afford protection against contacts welding of contactors under short - circuit conditions. The same procedure is obviously applicable to fuses suitable for types 1 and 2 of short - circuit co - ordination.

## VII. REFERENCES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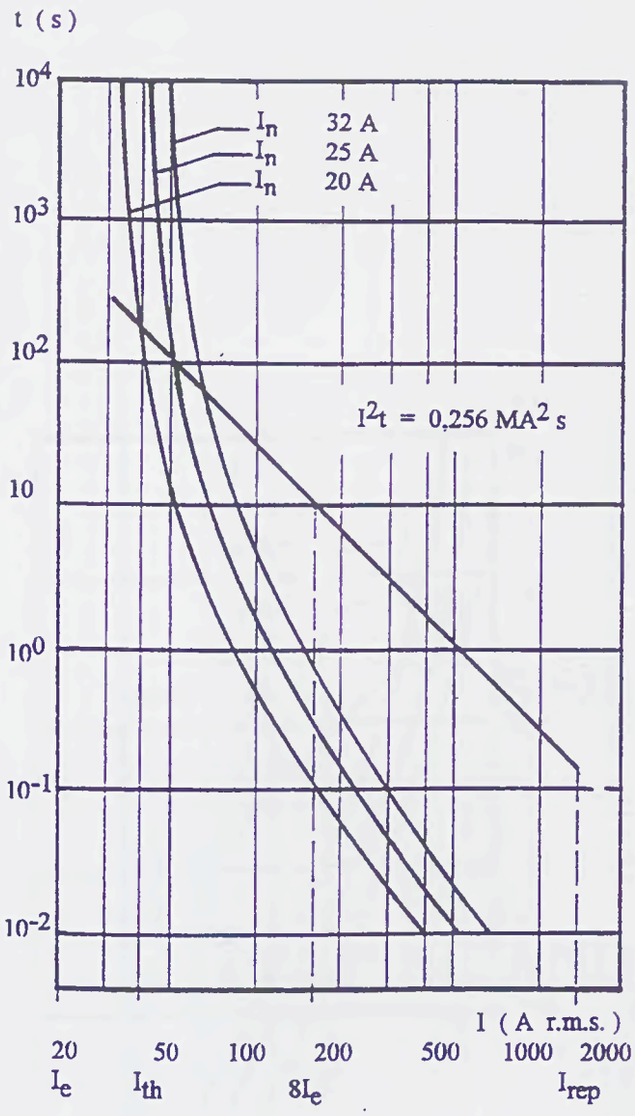

t ( s )
$10^4$
$10^3$
$10^2$
10
$10^0$
$10^{-1}$
$10^{-2}$
$I_n$ 32 A
$I_n$ 25 A
$I_n$ 20 A
$I^2t$ = 0,256 $MA^2$ s
I ( A r.m.s. )
20
$I_e$
50
$I_{th}$
100
200
$8I_e$
500
1000
2000
$I_{rep}$

Fig. 3

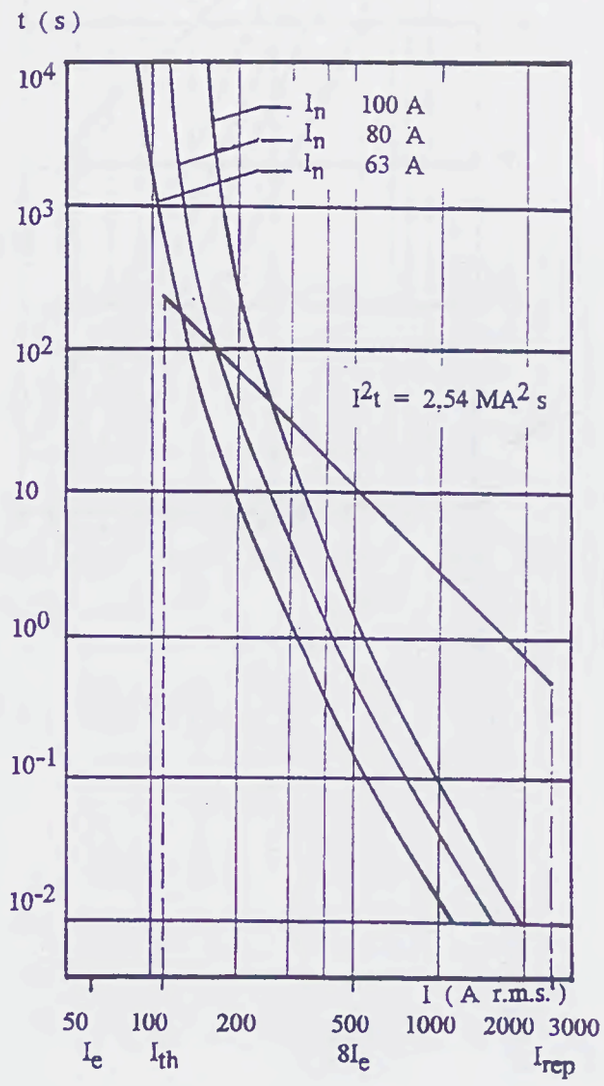

t ( s )
$10^4$
$10^3$
$10^2$
10
$10^0$
$10^{-1}$
$10^{-2}$
$I_n$ 100 A
$I_n$ 80 A
$I_n$ 63 A
$I^2t$ = 2,54 $MA^2$ s
I ( A r.m.s. )
50
$I_e$
100
$I_{th}$
200
500
$8I_e$
1000
2000
3000
$I_{rep}$

Fig. 4

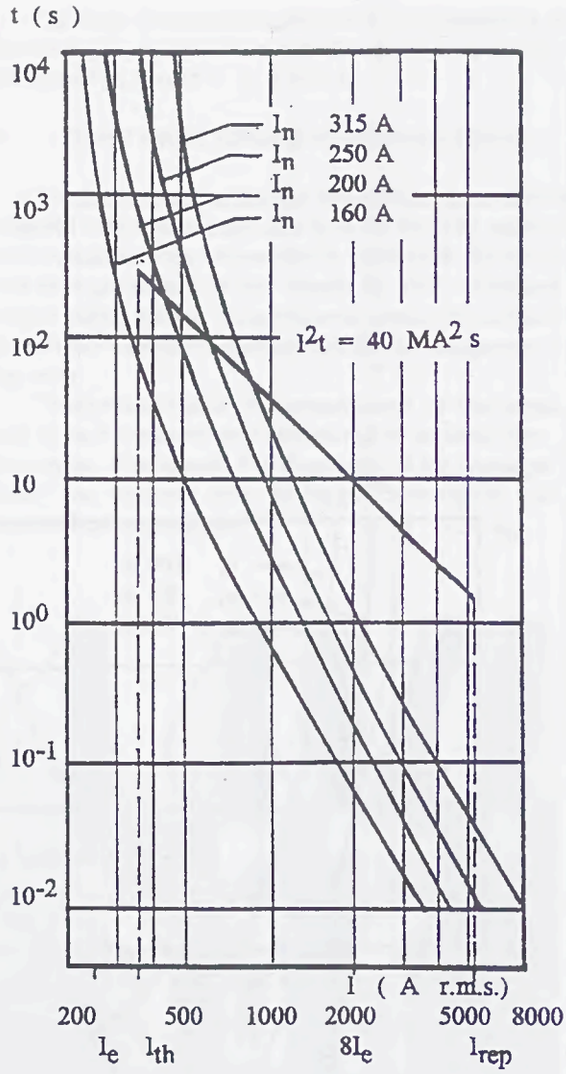

t ( s )
$10^4$
$10^3$
$10^2$
10
$10^0$
$10^{-1}$
$10^{-2}$
$I_n$ 315 A
$I_n$ 250 A
$I_n$ 200 A
$I_n$ 160 A
$I^2t$ = 40 $MA^2$ s
I ( A r.m.s.)
200
500
1000
2000
5000
8000
$I_e$
$I_{th}$
$8I_e$
$I_{rep}$

Fig. 5

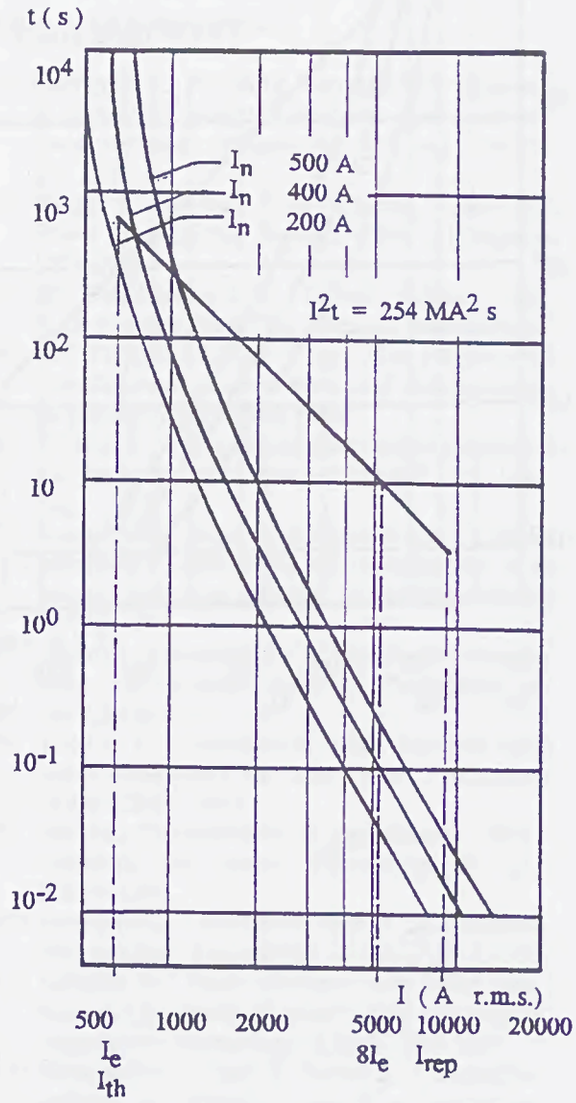
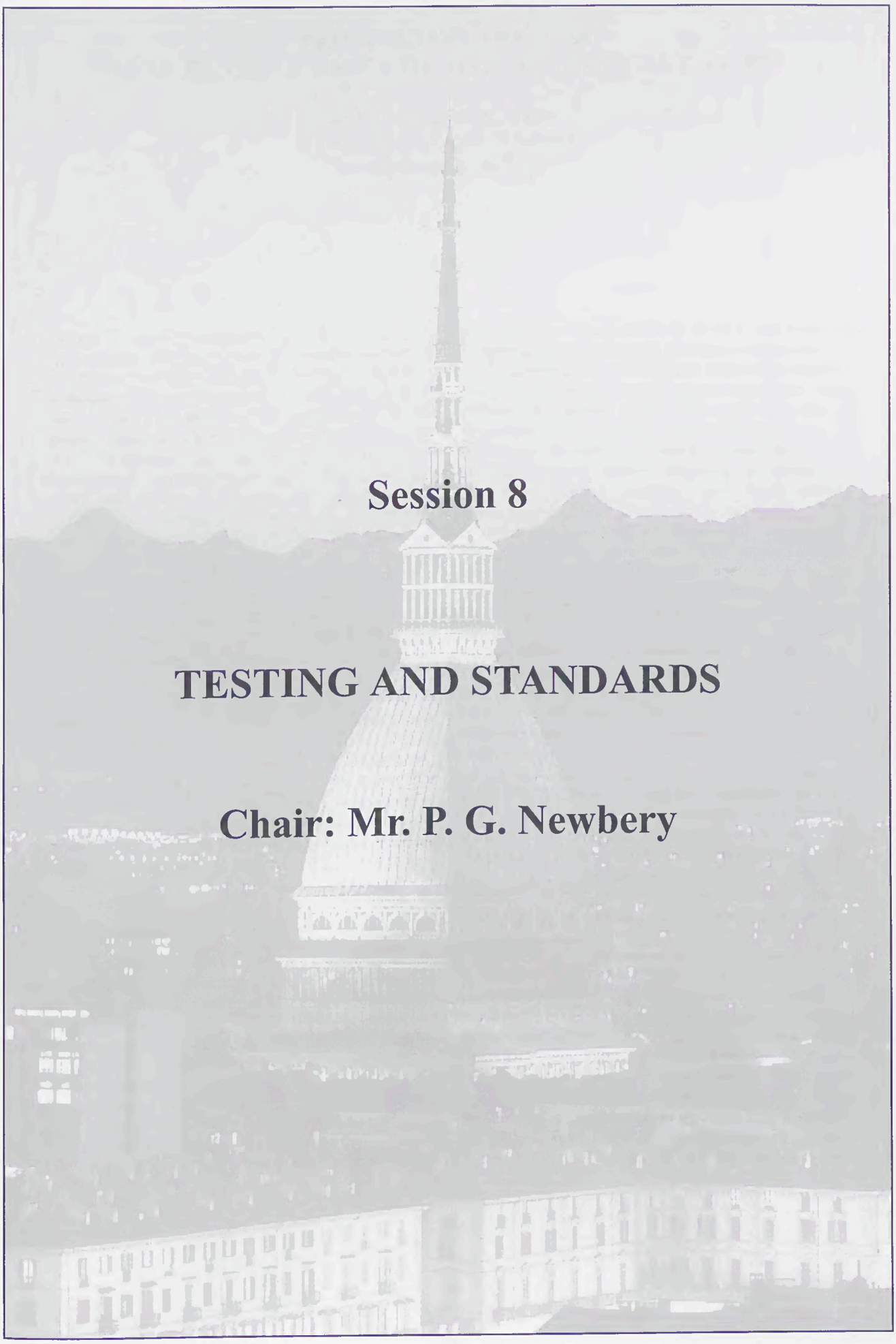

t ( s )
$10^4$
$10^3$
$10^2$
10
$10^0$
$10^{-1}$
$10^{-2}$
$I_n$ 500 A
$I_n$ 400 A
$I_n$ 200 A
$I^2t$ = 254 $MA^2$ s
I ( A r.m.s.)
500
1000
2000
5000
10000
20000
$I_e$
$I_{th}$
$8I_e$
$I_{rep}$

Fig. 6



# Session 8

# TESTING AND STANDARDS

## Chair: Mr. P. G. Newbery