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IEC 62870 ED.1
Safety secondary circuits in series circuits – General safety requirements

a new draft

Electrical installations for lighting and beaconing of aerodromes

Personal Safety
IES ALC Conference

Tucson, 2013-10-24

Maintenance work vs personal safety

Electrical installations for lighting and beaconing of aerodromes

Maintenance of series circuits is necessary work such as relamping or exchange of luminaires, done on every airport worldwide.

A lot of maintenance staff is doing this work.

Are they experienced with series circuit technology?

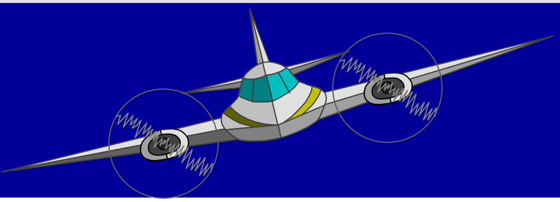
Do they all know that the series circuit voltage could reach up to a.c. 5kV rms?

Do they work safely under this conditions?

Airfield ***Maintenance*** *Technician - Birmingham Airport*

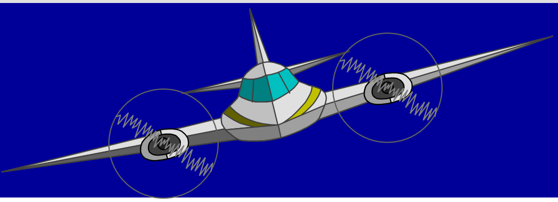
Do they really switch off the circuit before working?

Do they follow the rules according to
IEC 61821:2002-03
- **Maintenance of aeronautical ground lighting constant current series circuits?**



Standards and technical specifications of IEC to be met :

IEC 61821	maintenance
IEC 61822	CCRs
IEC 61823	transformers
IEC/TS 61827	luminaires
IEC/TS 62143	life cycle methodology
IEC/TS 62100	cables



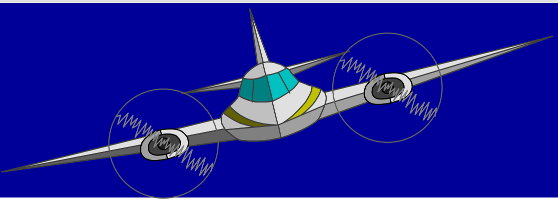
Actual situation

What might be found on an airport?

- More and more employment of external companies (outsourcing of maintenance work).
  - professional competence is at least questionable
  - experience mostly only with conventional wiring (parallel circuit)
  - maintenance work often will be done at live circuits against the rules

But: responsibility will remain at the airport authorities

And: new technologies will cause new requirements



Actual situation

Why is it as it is?

Aeronautical ground lighting rates among optical navigation systems and as such is subject to special requirements with respect to availability.

Insulation faults in the series circuit are thus tolerated and do not lead to automatic shutdown of supply.

With respect to availability, broken lamps have to be replaced immediately within a short time and with shortest interruption of the system and **to the lowest costs.**

It's a commercially driven process.

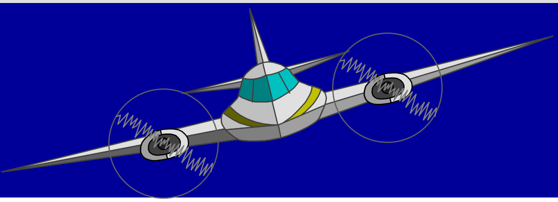
But personal safety shall not be influenced by money!

Hazard analysis

The change to LED-technology may be a short open window to go for more personal safety in the future.

With the knowledge in mind of the actual situation the German national committee started thinking, powered by major German Airports, how to improve maintenance work and to find out the real risks for human health when working at live secondary circuits, which results in a German standard (VDE V 0161-11), which has been shifted to IEC.

In a hazard analysis of constant current series circuits for aeronautical ground lighting the risks and endangerments from the view of protection of individuals work on series secondary circuits have been documented.



Hazard analysis content and title

Touch voltages and estimations of endangerment from the view of the protection of individuals work on the secondary winding side of a series circuit transformer in series electric circuits*.*
Confrontation of the traditional supplies and a supply of ***s****afety* ***e****xtra* ***l****ow* ***v****oltage (SELV).*

Extract of the content:

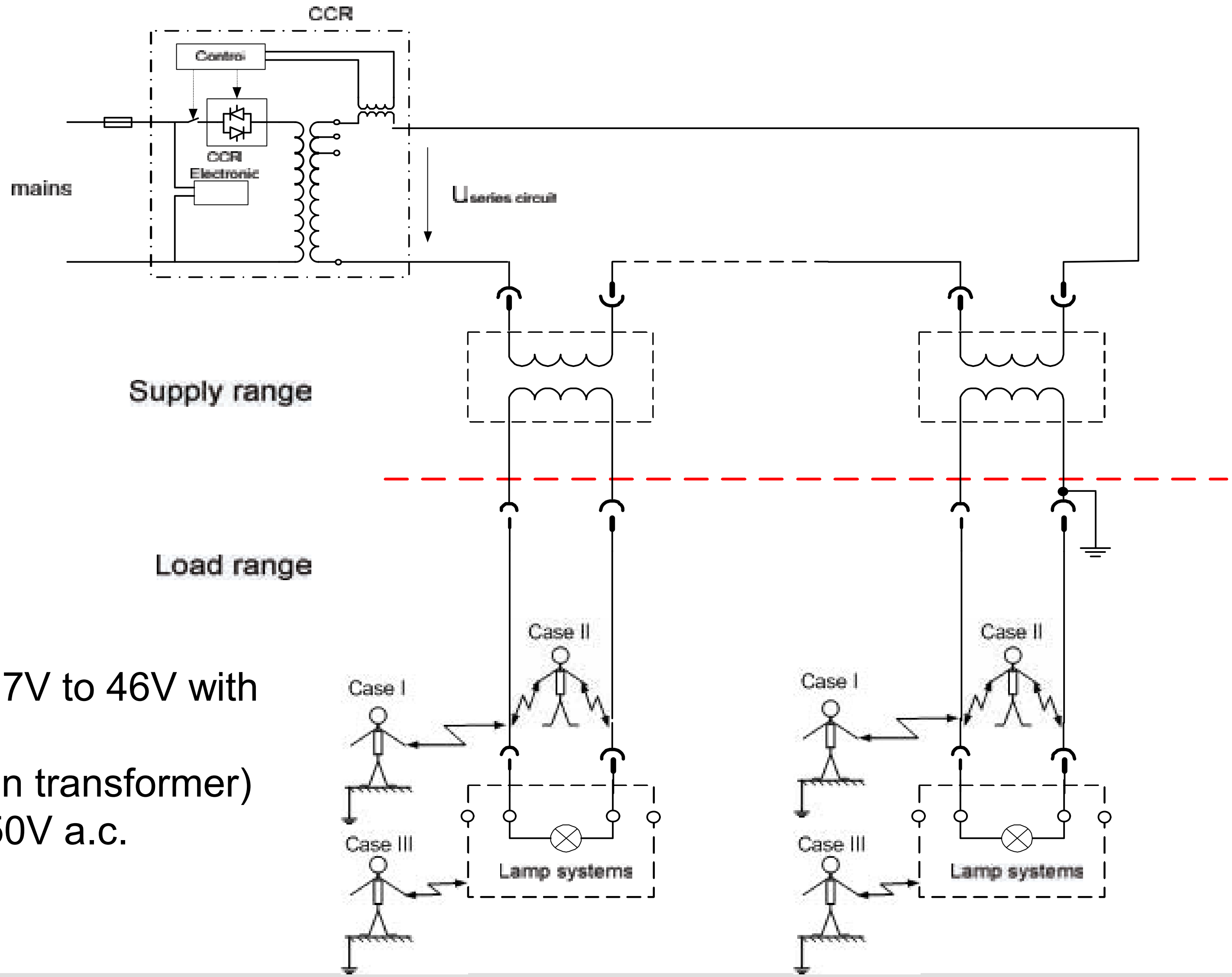
- FMEA and hazard analysis from experiences
- Hazard potential and impacts
- Example of calculation of voltage occurring
- System approach for safe working at the luminaire

Which will be explained in the following slides.

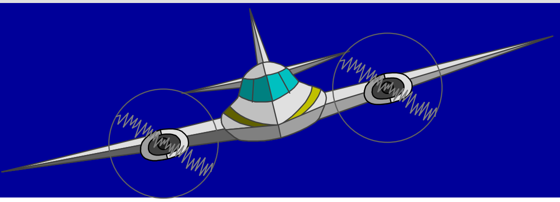
Endangerment
Basic information

Electrical installations for lighting and beaconing of aerodromes

Where and how will a hazard occur?



Operating voltages: 7V to 46V with nominal load
Touch voltages (open transformer)
Up to now > 50V a.c.



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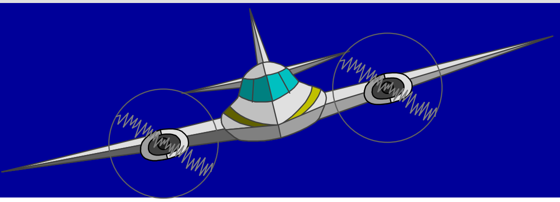
Which rated voltage level can be found at the transformer output?

When you read the IEC standard 61823 (transformers) you´ll find in table 1 with the primary current at 6.6A and with the secondary circuit open the voltage at secondary connector terminals shall not exceed the limits given**:**

Table 1 – Transformer characteristics

Nominal power W	**Rated power** W		**Load (resistive)** Ω			**Maximum open circuit voltage** V
	Low	**High**	**Low (maximum)**	**Nominal**	**High (minimum)**	**50 Hz and 60 Hz**
30	25	40	0,57	0,69	0,92	20
45	35	60	0,80	1,03	1,38	20
65	50	85	1,15	1,49	1,95	30
100	80	125	1,84	2,30	2,87	40
150	120	178	2,75	3,44	4,13	
200	160	230	3,67	4,59	5,28	
300	220	338	5,05	6,89	7,81	



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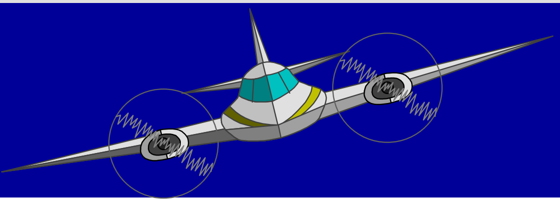
An equivalent value can be found within FAA advisory circular AC No. 150/5345-47C, Table 2:

Table 2. Isolation Transformer Electrical Characteristics

Type	Wattage (Watts)	Primary Amps	Min. Power Factor	Min. Efficiency (Percent)	Secondary Full Load Amperes	Secondary Short Circuited Amperes	Load Ohms	Secondary Maximum Open Circuit Voltage - RMS	IEC-values Maximum Open Circuit Voltage - RMS
L-830-1	30/45	6.6	0.95	80	6.53-6.67	6.6-7.1	1.15	25	20
L-830-2	30/45	20.0	0.95	80	6.53-6.67	6.6-7.1	1.15	25	
L-830-3	65	6.6	0.95	80	6.53-6.67	6.6-7.1	1.60	30	30
L-830-4	100	6.6	0.95	85	6.53-6.67	6.6-7.1	2.44	70	40
L-830-5	100	20.0	0.95	85	6.53-6.67	6.6-7.1	2.44	70	
L-830-6	200	6.6	0.95	90	6.53-6.67	6.6-7.1	4.82	100	70
L-830-7	200	20.0	0.95	90	6.53-6.67	6.6-7.1	4.82	100	
L-830-8	300	6.6	0.95	90	19.8-20.2	20.0-22.0	0.90	70	110
L-830-9	300	20.0	0.95	90	19.8-20.2	20.0-22.0	0.90	70	
L-830-10	300	6.6	0.95	90	6.53-6.67	6.6-7.1	8.25	135	
L-830-11	300	20.0	0.95	90	6.53-6.67	6.6-7.1	8.25	135	
L-830-12	500	6.6	0.95	90	19.8-20.2	20.0-22.0	1.35	70	
L-830-13	500	20.0	0.95	90	19.8-20.2	20.0-22.0	1.35	70	
L-830-14	500	6.6	0.95	90	6.53-6.67	6.6-7.1	12.0	230	
L-830-15	500	20.0	0.95	90	6.53-6.67	6.6-7.1	12.0	230	
L-830-16	10/15	6.6	0.95	70	6.53-6.67	6.6-7.1	0.34	8.0	
L-830-17	20/25	6.6	0.95	70	6.53-6.67	6.6-7.1	0.57	8.0	
L-830-18	150	6.6	0.95	85	6.53-6.67	6.6-7.1	3.58	70	60
L-830-19	150	20.0	0.95	85	19.8-20.2	20.0-22.0	3.58	70	

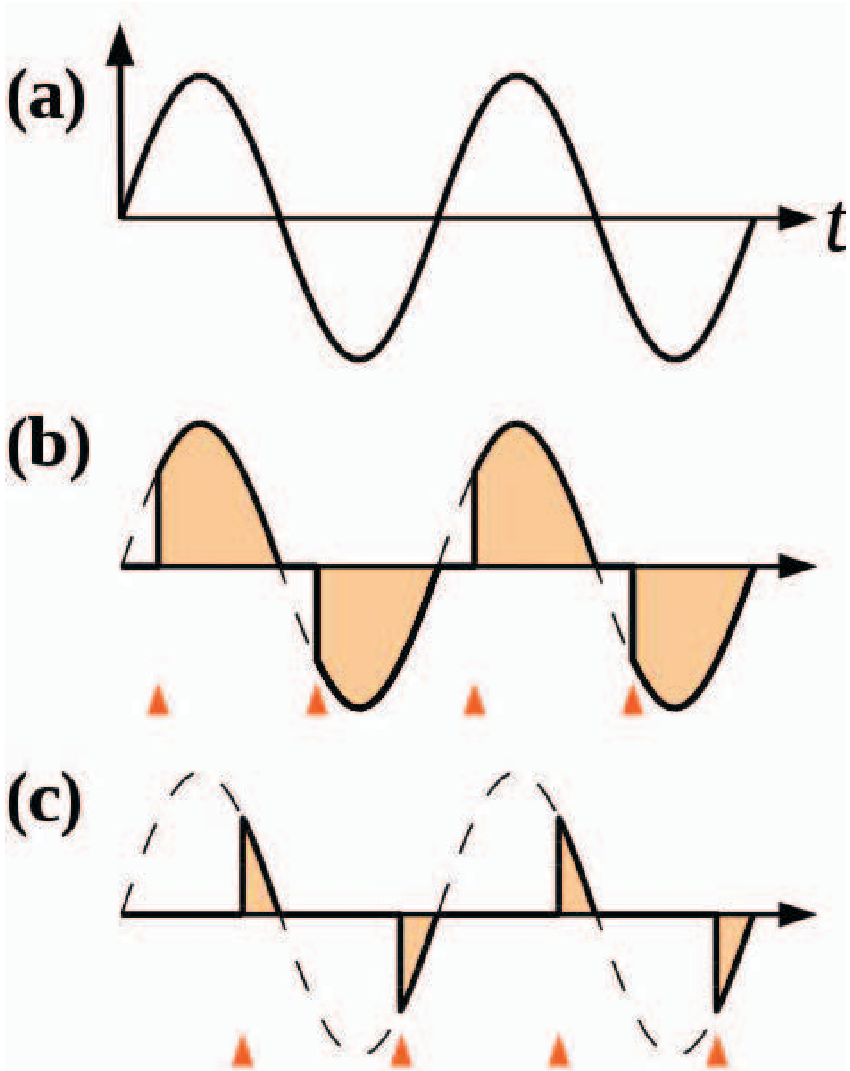


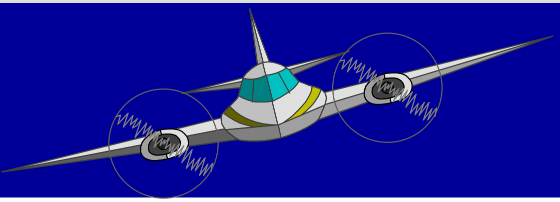
Endangerment
Basic information

But the given maximum open circuit output voltage is only valid for testing in the lab with sinusoidal input voltage (a).

Most of the CCR's use thyristors with phase angle control for supplying the series circuit and don't produce sinusoidal voltage especially in lower current steps, which is the main use (b, c).

In a usual series circuit we don't have a single transformer, mostly we have a number of transformers.





Endangerment
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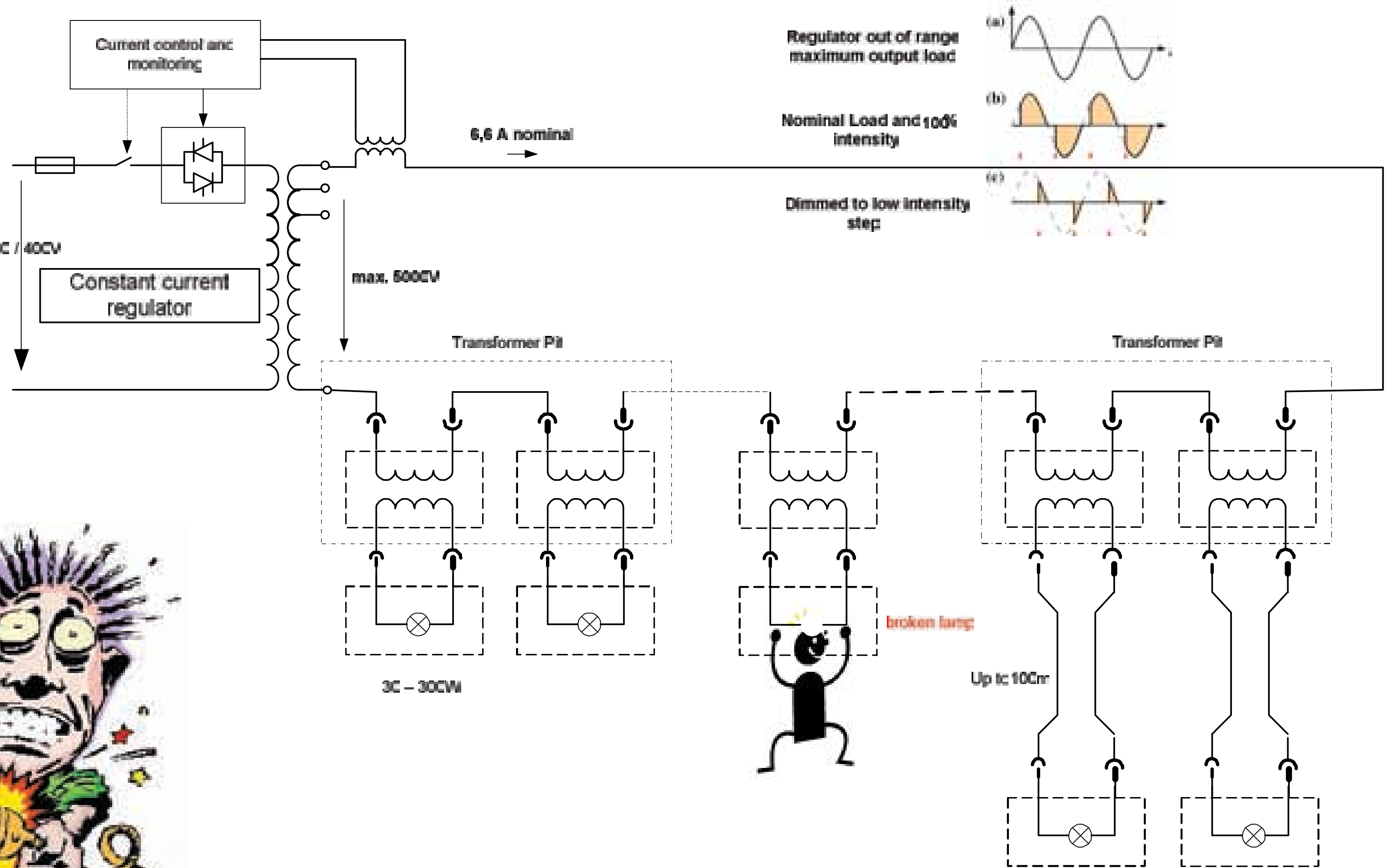
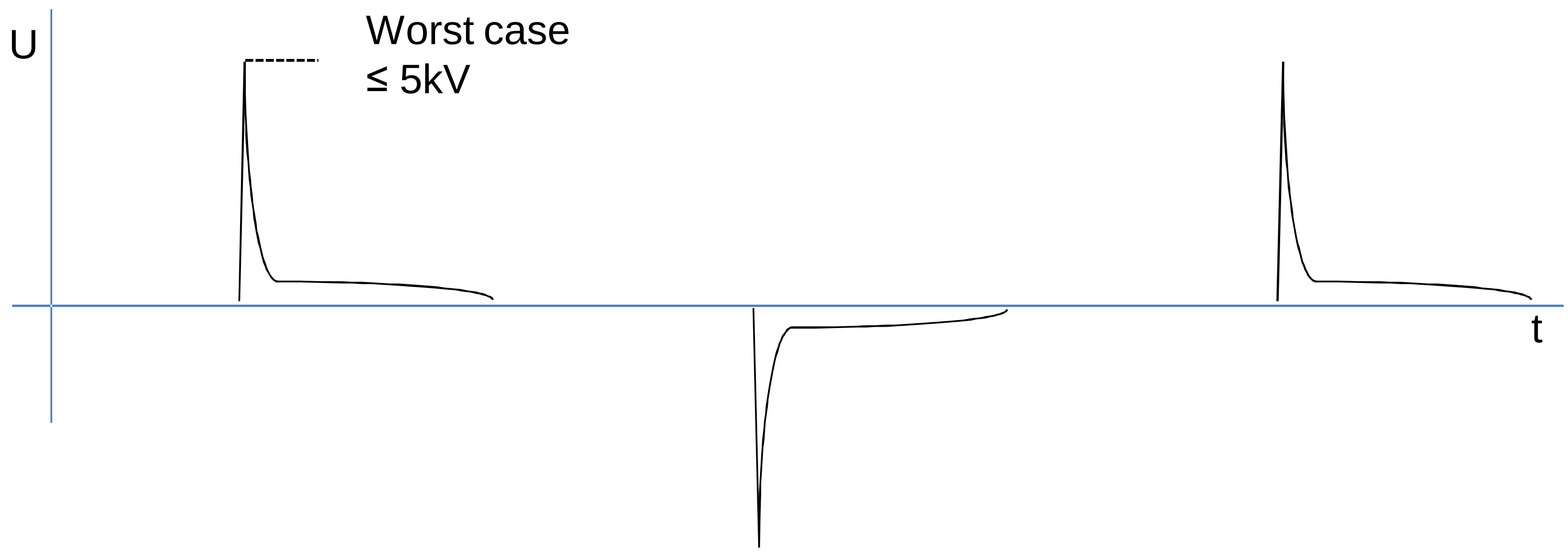
The impact of that situation is that the series circuit supply voltage can reach up to 5kV (30kVA)



The voltage at that open transformer will follow the shape:



Endangerment
Basic information

The voltage can be calculated for an example with the following assumptions:

- number of lights in series circuit: 60
- transformer rating: 150W
- lamp load: 100W
- length of series circuit: 6km (19 685ft)

Which gives:

- load resistance for the lamp transformer 2.7Ω (100W lamp 2.3Ω plus secondary cable 0.4Ω)
- series circuit length 6km which results in the case of 3Ω/km in a cable resistance of 18Ω.
- resistances of the lamp transformer R1 = R2 = 0.17Ω

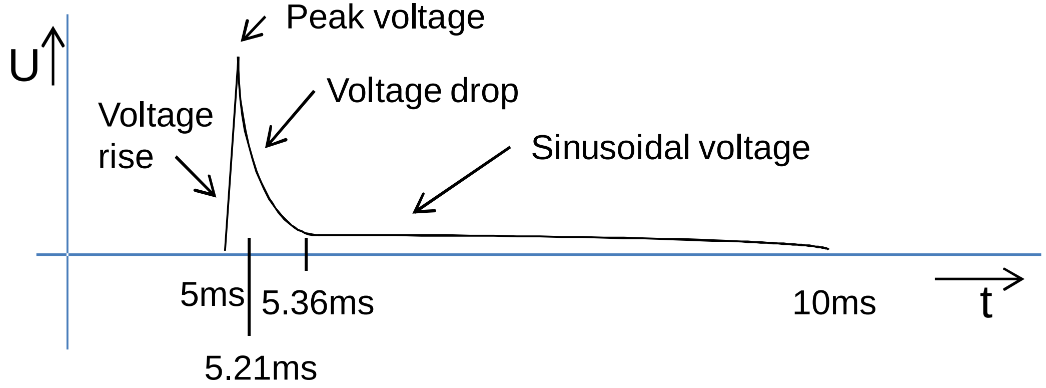
is the result for the feed transformer setting voltage 1500V, U peak= 2121V (voltage peak value 1500*√2) with a current operating angle of 120° (6.6ms) at 6.6A.

Endangerment
Basic information

Electrical installations for lighting and beaconing of aerodromes

With that data given the voltage can be calculated (@ 50Hz) to:

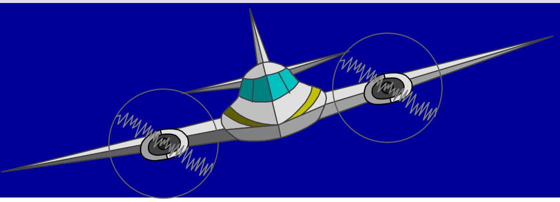
- Voltage rise with 5kV/ms within 0.21ms to1050V (peak voltage)
- Voltage drop acc. to e-function within 3τ (3 x 0.05ms)
- Further 4.64ms 47V sinusoidal (60V x 5.2A/6.6A)



That results in a rms voltage of ca. 154V on the secondary of an open running lamp transformer with a rated power of 150W!

$$\left(\sqrt{\frac{1}{10ms}\int_{5,0ms}^{5,21ms}\left(\frac{5kV}{ms}(t-5ms)\right)^2 dt} + \sqrt{\frac{1}{10ms}\int_{5,21ms}^{5,36ms}\left(1050V\, e^{-(t-5,21ms)/0,1ms}\right)^2 dt} + \frac{5,2A}{6,6A}\, 60V\sqrt{2}\sqrt{\frac{1}{10ms}\int_{5,36ms}^{10ms}(\sin\omega t)^2\, dt}\right) 0,9$$

Remember: operating voltage ≈15V (100W lamp), max. open circuit voltage acc. IEC = 60V



Endangerment
Basic information

The precise derivation of the relevant data can be seen in the Hazard analysis document.

The table on the right shows the voltage values of different rated power Transformers with the same series circuit conditions as above calculated.

Rated power	**Voltage at open circuited lamp transformer with phase controlled sinusoidal supply**
45W	67V
65W	87V
100W	115V
150W	154V
200W	185V

Conclusion:

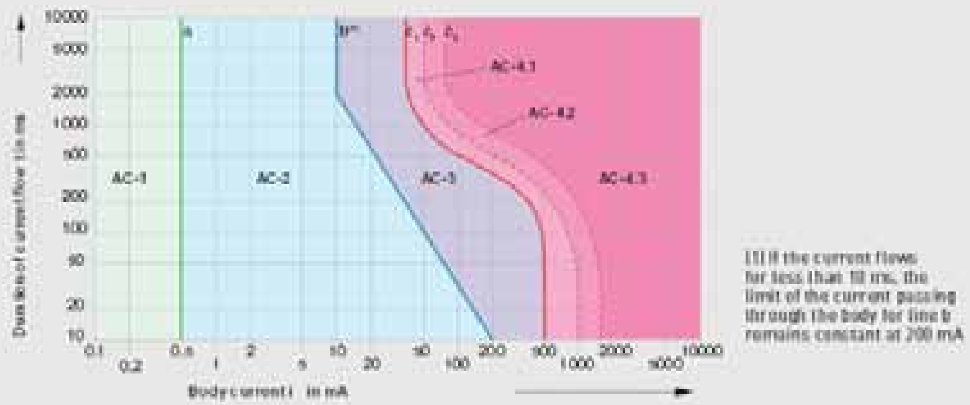
If a lamp transformer is operated with phase controlled current and the connected light is in such a manner defective that the lamp transformer is openly operated, then **the voltage exceeds** on the secondary winding **the value of 50 V rms.**
Therefore exists a hazard during contact of the connection poles of an openly operated lamp transformer.

A safe separation of the primary to the transformers secondary is not required for a actual standard transformer!

Hazards and health effects

The following figure shows the hazard threshold for an electric shock:

Time/current curves showing the effects of 15 to 100 Hz alternating current on humans



Zone	Physiological effects
AC-1	Generally no reaction
AC-2	Generally no dangerous physiological effect
AC-3	Generally no organic damage. Probability of muscle contractions and breathing difficulties if current flows for longer than 2 s. Reversible interference in the formation of cardiac impulse propagation without ventricular fibrillation, increasing with the intensity of the current and the flow period.
AC-4	Increasing with the current intensity and duration, pathophysiological effects such as cardiac arrest, respiratory arrest and severe burns can occur in addition to the effects of zone AC-3. AC-4.1 : Probability of ventricular fibrillation up to approximately 5% AC-4.2 : Probability of ventricular fibrillation up to approximately 50% AC-4.3 : Probability of ventricular fibrillation greater than 50%

Notes to Fig. 1

Current pathway	Impedance (Ω)
Hand - hand	1000
Foot – foot	1000
Hand – foot	750
Hands – feet	500
Hand – brest	450
Hands – brest	230
Hand – buttock	550
Hands – buttock	300

Impedances for alternating current 50Hz (acc. to IEC 60479-1)

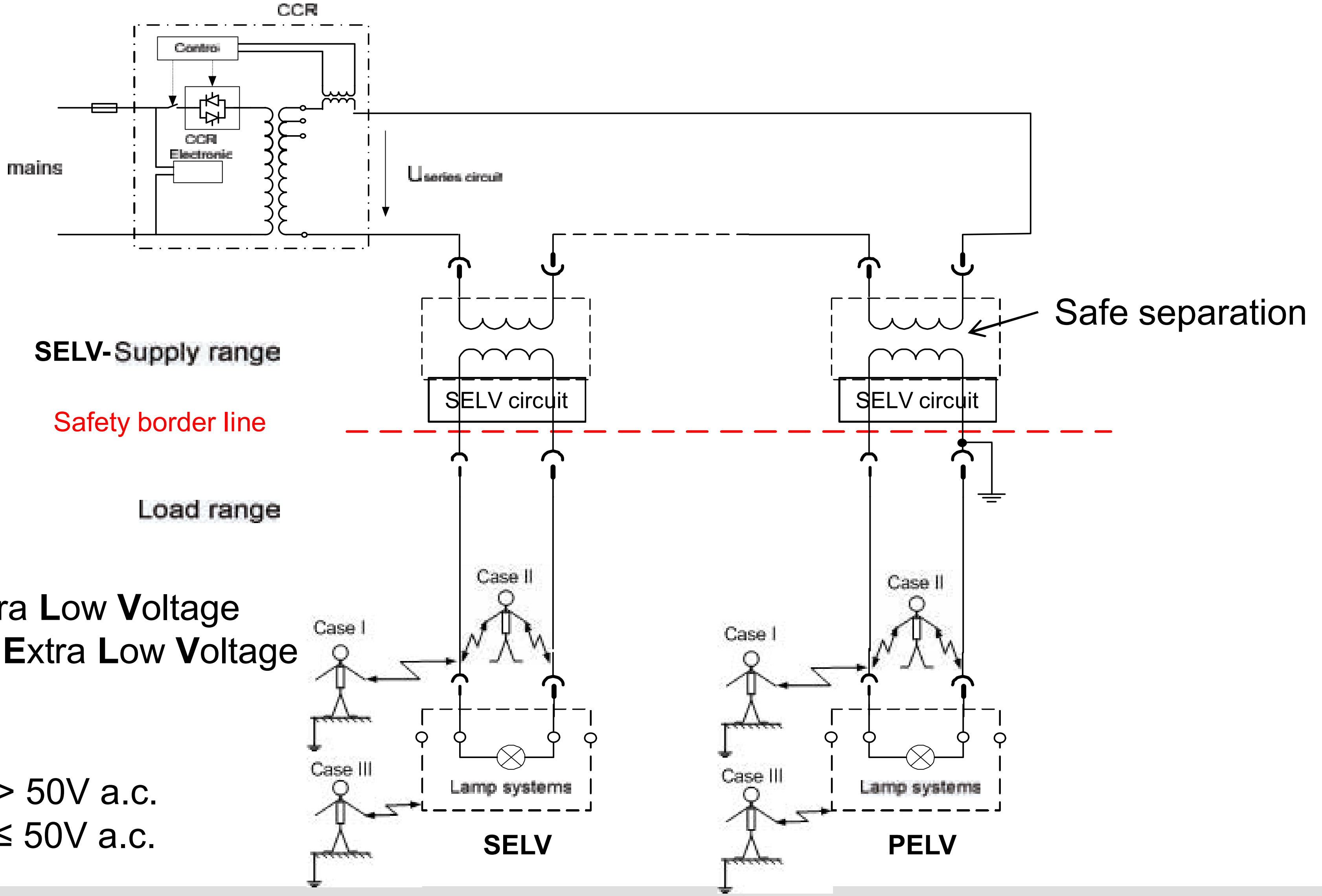
Fig.1: Current time effect diagram for alternating current 15-100Hz (for ventricular fibrillation current pathway left hand to both feet) from IEC/TS60479-1

I=50mA$_{rms}$ is regarded as the highest hazard threshold upon ventricular fibrillation is probable.

Improvement

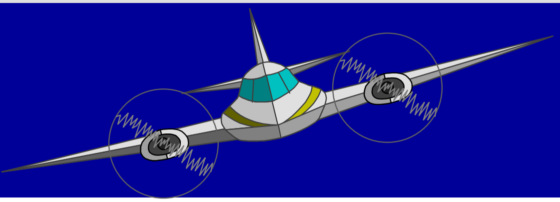
Electrical installations for lighting and beaconing of aerodromes

How may a hazard to personal safety be minimised?



SELV **S**afety **E**xtra **L**ow **V**oltage
PELV **P**rotective **E**xtra **L**ow **V**oltage

Touch voltages
Up to now > 50V a.c.
with SELV/PELV ≤ 50V a.c.



Protective measures

Electrical installations for lighting and beaconing of aerodromes

What are the protective measures?

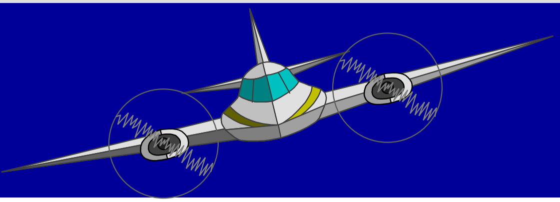
SELV and PELV measures are defined within IEC 60364-4-41(*Low-voltage electrical installations- Protection for safety- Protection against electric shock*)

This protective measure requires:

- Limitation of voltage in the SELV or PELV system to the upper limit of 50V a.c. or 120 V d.c. (see IEC 60449)

and

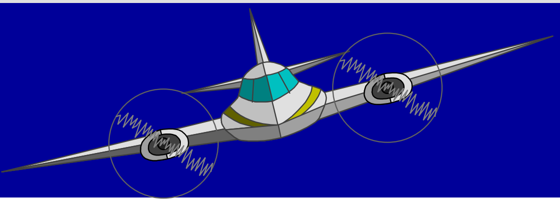
- protective separation of the SELV or PELV system from all other than SELV and PELV circuits and basic insulation between the SELV or PELV system and other SELV or PELV systems



The new standard IEC 62870 ED1.

The new preliminary standard IEC 62870 ED1. requires for that reason for operating an electronic lamp system **a safety extra low voltage** in accordance with IEC 61140 (Protection against electric shock – Common aspects for installation and equipment).

Thus also working on the secondary winding „of the safe “series circuit transformer under voltage without cutting off the primary becomes acceptable.



The new standard
IEC 62870 ED1.

This means for the safety extra low voltage supply and the installation:

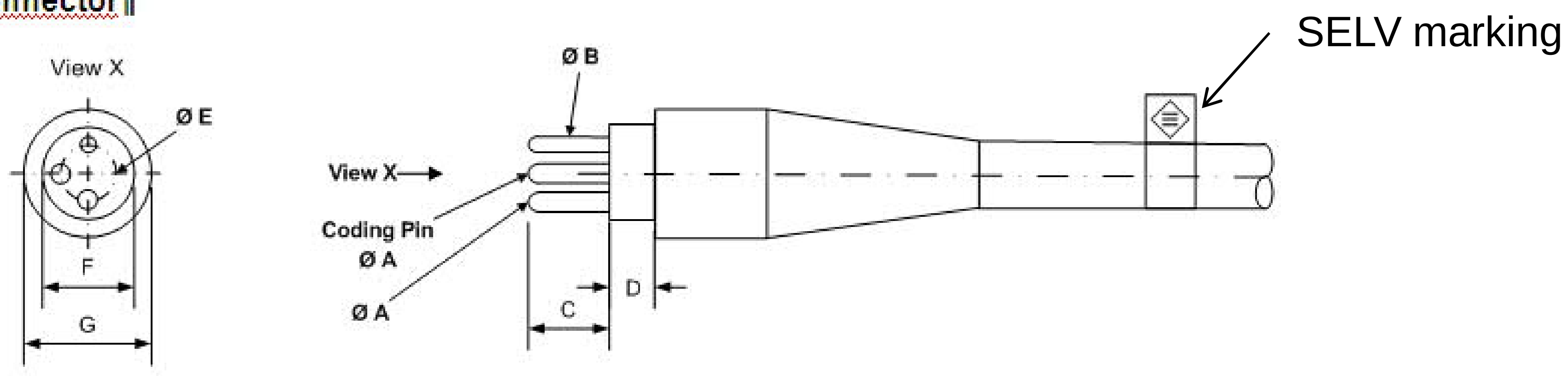
- Secure electrical insulation between the primary winding and the secondary winding of the series circuit transformer by the structure and the insulation and its dielectric strength of the transformer.
- Delimitation of the secondary alternating voltage on 50 V a.c.
- Delimitation of secondary DC voltage on 120 V d.c..
- No operational grounding of the safety extra low voltage supply or PELV.

The new standard IEC 62870 ED1.

Electrical installations for lighting and beaconing of aerodromes

For that purpose we decided to modify the existing FAA-connector:

SELV-connector¶



DIMENSIONS	MILLIMETERS
A	3.937 ± .025
B	3.150 ± .025
C	15.875 ± .381
D	8.712 + .787, -.000
E	11.049 ± .254
F	18.415 + .508, -.000
G	25.40 + .000, -.787

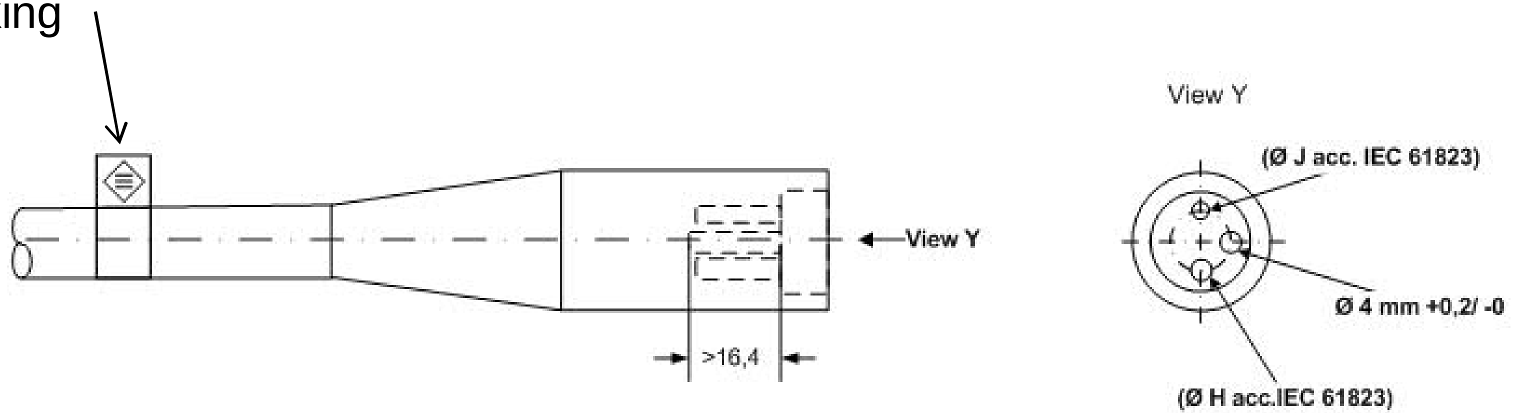
(A) SELV-Plug Style 1

Connections between SELV assemblies shall be unambiguously identifiable in the mated and unmated condition as SELV connection by the maintenance personnel.

The new standard IEC 62870 ED1.

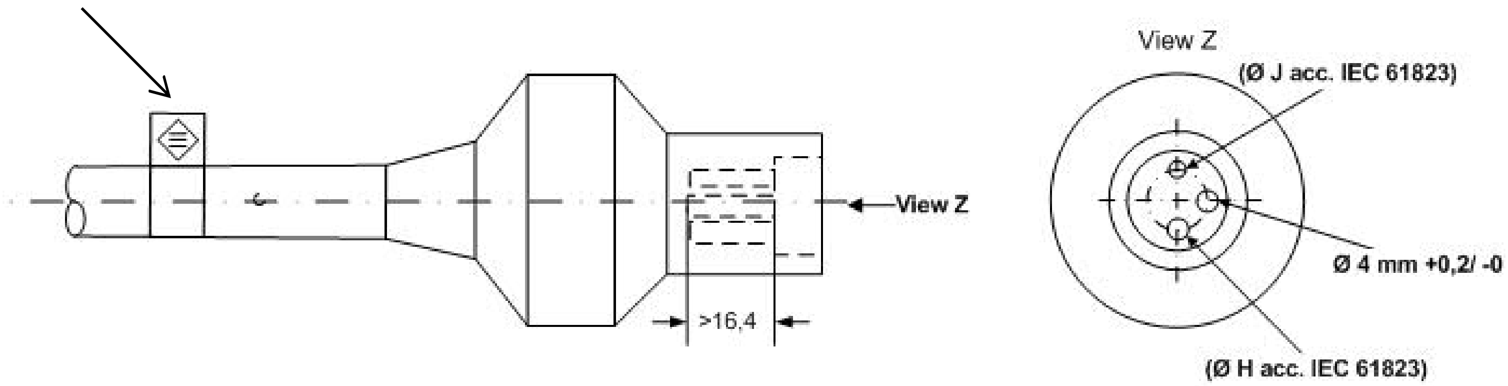
Electrical installations for lighting and beaconing of aerodromes

SELV marking

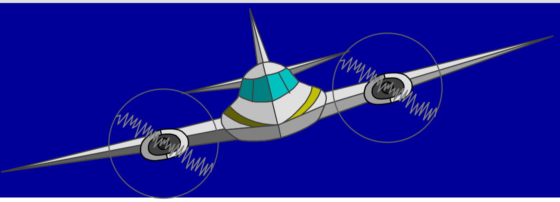


(B) SELV-Receptacle, Style 7

SELV marking



(C) SELV-Receptacle, Style 8



Summary in a nutshell

Electrical installations for lighting and beaconing of aerodromes

- **Actual situation** on an airport: sometimes **changing lamp source without cut off the primary circuit**
- **Hazard analysis** of constant current series circuits for aeronautical ground lighting **shows the risks and endangerments for personal safety**
- **Improvement of personal safety at maintenance work** such as relamping or change of luminaires in the field **using SELV circuits**
- **Creating a new IEC standard: IEC 62870 Ed.1**: Electrical installations for lighting and beaconing of aerodromes – Safety secondary circuits in series circuits – General safety requirements
- **Creating a new (SELV)connector**

This will allow: changing lamp source without cut off the primary circuit without restriction to personal safety.

Some questions

- how about changing lamp source without cut it the primary circuit?
- how are your experiences in the field?
- would you confirm that maintenance has to be improved particularly in personal safety regards?
- What do you think?
- What about the modified connector?

Thank you for your attention!