UV Curing Technology

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Content:

1. Advantages of UV technology

The significance of radiation curing as a basis of almost emission-free coating procedures has been constantly growing over the past years. Besides VOC-reduction and avoidance there are a number of further reasons for the use of the UV-curing technique that can't be ignored any more by today's and future coating procedures.

Some of the reasons are:

- Economy due to reduced curing times, high production speeds, shorter production lines and low energy costs.
- Production of scratch resistant coatings with good mechanical and chemical properties. Cured surfaces are solvent resistant.
- Immediate post processing like polishing and stacking and less dusting as a result.
- UV-curing requires only small application amounts. There is a possibility of re-using unused coating materials as they can only be cured in the UV-lamp area.
- Low heating up of the substrate surface.
- Good tolerance of the UV-varnishes towards other varnish materials.

UV-technique has become a safe and mature technology. Today radiation protection, ozone and working place safety are beyond discussion. During drupa 2000 this fact has been clearly pointed out at the UV-forum of the trade association of the paper and printing industry in cooperation with French and British safety organizations.

The use of UV-curing ink and varnish systems offers a possibility of meeting the EU-environmental laws which are becoming stricter and stricter.
Beside the water-based and powder technology UV is considered as one among three future technologies in the field of coating applications.

2. Current areas of application

The area of application of the UV-technology covers the graphics industry with its various printing and varnishing procedures, industrial applications as well as applications in the automotive industry.

As substrates paper, carton, plastics, metal, wood, corrugated boards or glass are used.

2.1 UV in the graphics industry

Depending on the varnish and printing process there is a variety of applications in the area of the graphics industry:
Folding boxes for cosmetics and drinks, business reports, cheque cards, identity cards, security papers, banknotes, forms, mailings, cheques, lottery tickets, packaging, advertising and price labels (for food, cosmetic and medical products), metal packaging like boxes and cans, bottle tops, yoghurt cups, compact disks, etc.

2.2 UV in industrial applications

UV-Technology in industrial applications is mainly used in the following areas: cross-linking of hotmelt PSA, silicone application on papers, PVC-floor varnishing, varnishing of decorative papers, etc.

2.3 UV in the automotive industry

UV-curing in the automotive industry was adopted in the automotive industry via component suppliers.
The following applications are state-of-the-art today: headlight lenses, reflectors, bumper guards, centre consoles,
instrument panels, indoor wood veneers, screen printing for instruments respectively measuring instruments, cylinder head gaskets, steering wheels, electronic circuit boards, UV-adhesives for antinoise-mats, so-called black parts (pumps, gears), car windows, etc.

From this short list which is by no means complete you can see the variety of UV-technology, partially also for three-dimensional objects.

3. Principles of UV-Technology

3.1 Spectral energy distribution

UV-radiation is a part of the electromagnetic radiation spectrum which is limited by X-radiation in the short wave area and by visible light in the longer wave area.
We can generally say that the shorter the waves are the more energetic is the radiation. UV-radiation is divided in three ranges:

UVC:	range: 100-280 nm
UVB:	range: 280-315 nm
UVA:	range: 315-380 nm

3.2 Energy balance

A UV-lamp consists of a closed quartz tube containing mercury. UV-radiation is technically created by electrical stimulation of the mercury in the quartz tube, whereby the spectral light distribution of a UV-lamp is determined by the gas filling.
Normally a mercury vapour lamp, besides producing UV radiation, also emits visible light and IR radiation. 100% of energy input is thereby converted in

- approx. 28% UV-radiation
- approx. 21% visible light
- approx. 33% IR-radiation
- approx. 18% dissipation (heat loss)

3.3 UV-lamp spectrum

Mercury lamps create a spectrum output that may be varied by means of additives.

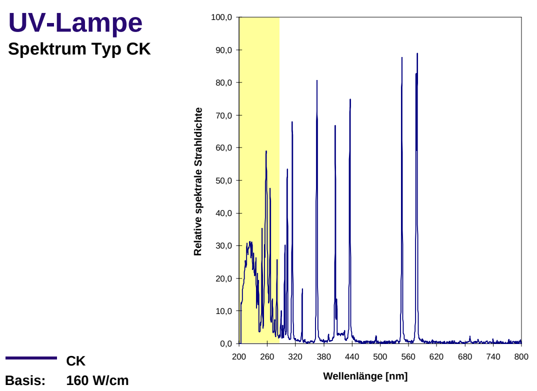

diagram 1: Mercury spectrum

Diagram 1 shows a standard mercury lamp used in almost 80% of all application cases. The lamp is mainly applied in the UVC-range below 250 nm

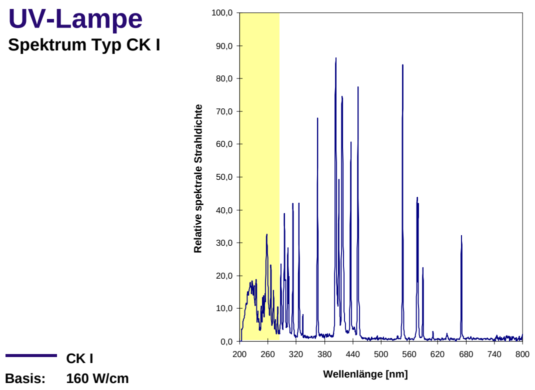

diagram 2: Gallium-spectrum

By means of Ga and In doping, the lamp spectrum is completed by intense characteristic curves in the range of 400-450 nm. This lamp type is mainly used in the visible long wave range for the curing of pigmented wood varnishes.

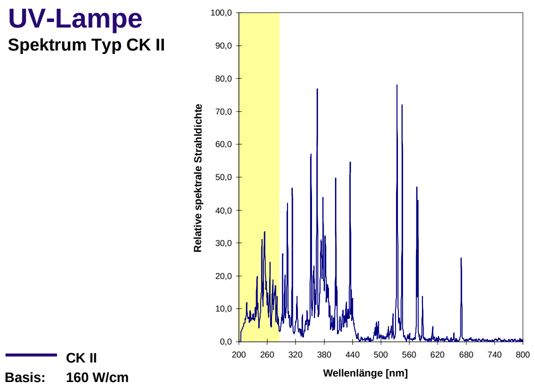

diagram 3: Iron-spectrum

By adding iron to mercury, a wide spectrum with high radiation densities consisting of many lines which are close to each other is designed in the medium to long wave range of 300-380 nm. Consequently, this lamp type is mainly used in the UVA range.

Various filter additives in the quartz glass facilitate the design of ozone-free UV-lamps for each lamp spectrum, whereby the filter edge is determined by the choice of material.

Medium pressure mercury lamps are available from IST with arc lengths of 100 to 2300 mm and with specific electric outputs of 80 W/cm to 200 W/cm depending on lamp length.

3.4 Reflector

The second important component of a UV-unit is the reflector. The UV-lamp emits radiation in all directions. Special reflectors are applied to make use of the radiation which is emitted in the direction of the lamp housing. A good and efficient reflector makes it possible that approximately 55% of the radiation reaching the substrate consists of reflected radiation. The following features are part of a good reflector:

a) Reflection material

It is known that aluminium has a very high efficiency of approx. 90% all over the complete spectrum. Disadvantageous for some applications are that its good reflection values of infrared radiation could raise the temperature of the substrate. Cold Mirror reflectors offer a further possibility. This reflector type permits a high reflection in the UV-range while visible light and IR-light pass the reflector. The temperature of the substrate is thereby reduced.

b) The quality of the reflector surface
Not only is the quantity of the reflected radiation but also its direction decisive for the reflector efficiency. We can generally say that the smoother the surface, the more directed and efficient is the UV-radiation reflected onto the substrate. Aluminium reflectors are therefore polished at IST or high temperature resistant glass is used as material for the CM-reflectors.

c) The reflector's geometry
Diverse reflector geometries can be used depending on the application field. Diagram 4 shows the patented IST 1-reflector both focusing and diffusing UV-light – a feature that makes this reflector type suited for universal applications. Diagram 5 shows the CMK-reflector both capable of focusing and diffusing.

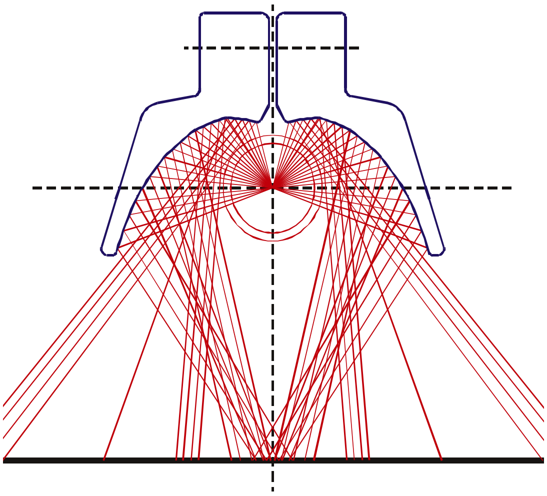

diagram 4: IST 1-reflector

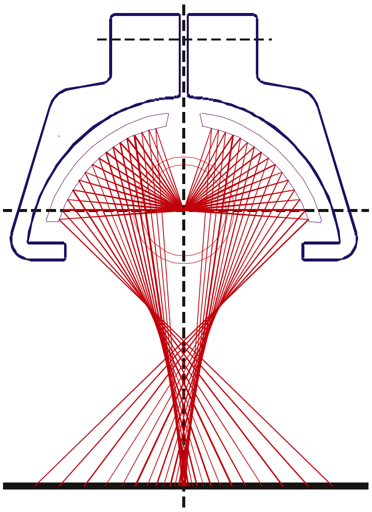

diagram 5: CMK-reflector

Furthermore elliptic reflectors can be used for focusing UV-light on one point. Parabolic reflectors create UV-light with vertical incidence on the substrate.
Depending on the unit type, the diverse reflector geometries are interchangeable.

3. 5 Power supply device – output control

There are principally two different ways of operating a UV-lamp:

a.) Mains-operated: shorter UV-lamps up to 500 mm can be directly operated from the mains supply.

b.) Transformer-operated: for longer UV-lamps up to 2.300 mm suitable transformers must be used to achieve the required igniting and arc voltage.

There are diverse possibilities of controlling the lamp output:

a) 2-step switching (50/100%)

b) 3- step switching (50/75/100%)

c) stepless lamp output control SLC (40-100%)

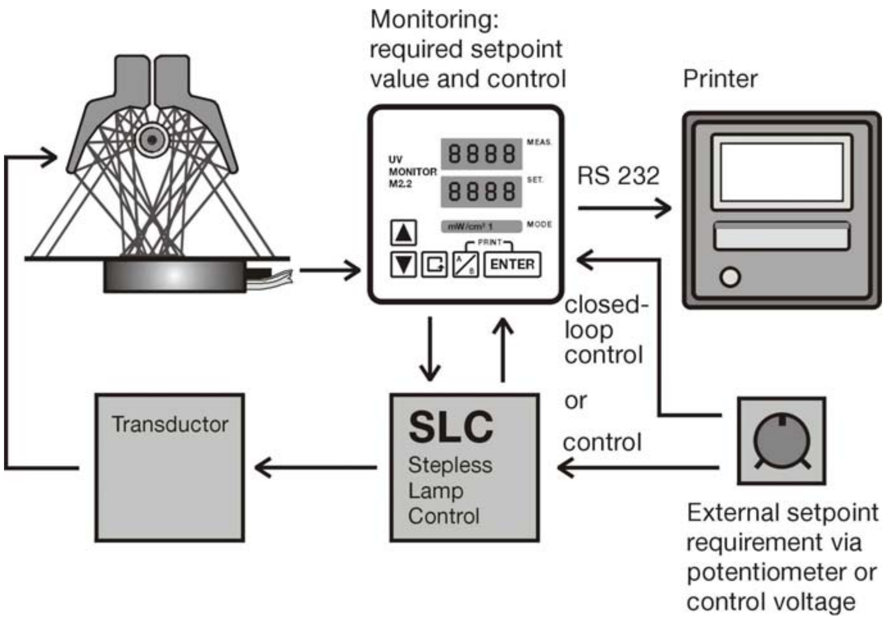

diagram 6: UV-monitor control loop

The benefit of SLC is the fact that the energy required at the moment can be adapted to the production speed. Using step switching, however, more energy may partially be consumed than is necessary.

Another development is the closed UV-control circuit combined with on-line-UV-measurement by means of a UV-sensor. It is not the installed, electrical output that is being adjusted here, but the actual UV-output reaching the object which is measured and/ or monitored.
There are several possibilities of using this UV-measurement:

a) UV-output measurement
In this system the measured UV-value is displayed. If the UV-value falls below the setpoint value, an acoustic or visual alarm will be activated. In case of SLC the required electrical output can be supplied subsequently if available.

b) UV-output control
With SLC, the measured UV-value may also be used as an electric set point value. It means that the SLC increases the electric output at the UV-lamp when the measured UV-value falls below the rated UV-value.

c) Speed-related UV-output control
In this variant the UV-limiting value is not fixed but varies according to changes in production speed. This ensures that the UV-radiation dose is always constant.

In all three processes the measured UV-value may be printed out for documentation purposes.

3.6 Unit control

Switch cabinets principally consist of an output and a control part. Control can be affected via contactors; the respective PLC-controls by diverse manufacturers can also be used.
The unit can either be directly operated at the switch cabinet or via operator terminals that may be positioned close to production.

These operator terminals facilitate a menu-assisted operation of a UV-unit. Among other things, jobs with a certain unit configuration can be stored and fault messages can be displayed.

4. Basic concepts of UV-modules

After both main components of a UV-unit have been presented, the UV-lamp and the reflector, they should be integrated in suitable UV-units in order to fulfil the demands made on cooling.

The main distinction is made between air-cooled and air/water-cooled units. Inerted systems have a special position. In these units cooling is effected via nitrogen which is circulated in a closed cycle within the lamp housing.

4.1 Air-cooled systems:

a) MBS®-System:

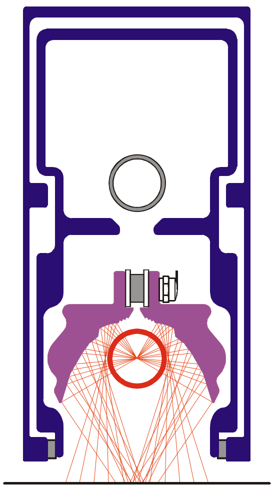

diagram 7: IST 2 rotary reflector in MBS® version

MBS® is the abbreviation of a modular building system and consists of a compact UV-lamp unit with external and internal housing made from extruded aluminium profiles. In this unit concept UV-lamp lengths up to 500 mm with specific outputs of up to 200 W/cm depending on the lamp length are used. Rotary reflectors are available both in aluminium design and as cold mirror (CMK). The new generation units have an inspection opening on top for UV-measurements that may be taken at stand-by operation with UV-measuring instruments developed and manufactured at IST METZ.

b) Lignocure-System

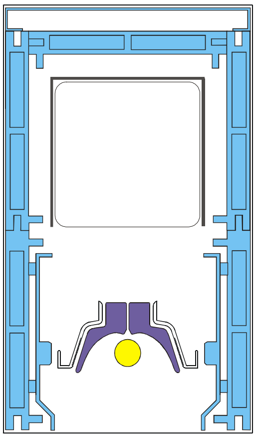

diagram 8: Lignocure-System

The lamp housing of the Lignocure-system is made of solid, extruded profiles.
The UV-lamp output is limited to 120 W/cm at lamp lengths of up to 2300 mm. There is the possibility of using both aluminium reflectors with any kind of geometry and cold mirror reflectors (CMK).

4.2 Luft/wassergekühlte Systeme

a) BLK® System

BLK® is the German abbreviation of Basic-Air-Cooling and is a combination of air cooling of UV-lamps and reflector and water cooling of absorber and shutters. The compact BLK-System is designed for outputs of up to 200 W/cm. The max. lamp length is at 2200 mm but in that case with reduced output. With BLK only CMK-mirror reflectors are used. They provide extremely high reflexion efficiency in UV whilst allowing the IR-radiation to pass through the reflector and be absorbed by the water and air cooled profile behind the reflector. From there heat is discharged from the housing via water cooling. The same applies to the heat development in the shutter area. The shutters automatically close in front of the UV-lamp in case of a stoppage to avoid an overheating of the substrate.
The new generation devices have a lateral inspection slot. UV-measurements can be taken with specially developed UV-meters at stand-by.

4.3 Inerted systems

There are principally two possibilities of designing UV inerted units. There are open systems and closed systems with separation between UV-lamp and reaction chamber.

a) Closed inerted UV-units

In closed systems the UV-lamp unit is separated from the reaction chamber by a quartz plate. This means that a conventional UV-unit is set up on a special substructure. Inert gas is supplied to the reaction chamber via a blade jet and a filling jet. Especially at higher speeds the function of the blade jet is to prevent air penetration by means of a nitrogen stream. The filling jet provides the correct residual oxygen concentration. Sealing measures at the inlet and outlet of the unit should be taken individually. They determine considerably the nitrogen consumption.
There are unit designs available both for a horizontal web and for an installation above chill rollers.
The benefit of the closed systems is above all their very compact design. As a disadvantage the UV-output attenuating quartz plate should be mentioned.
According to our measurements 20-25% UVC and each 5-10% UVB and UVA get lost due to the quartz plate. With an installed quartz plate the distance between UV-lamp and substrate is increased also causing further slight output losses.

b) Open inerted UV-units

Due to the mentioned disadvantages of the closed systems, a unit design working without quartz plate has been developed by IST METZ GmbH.

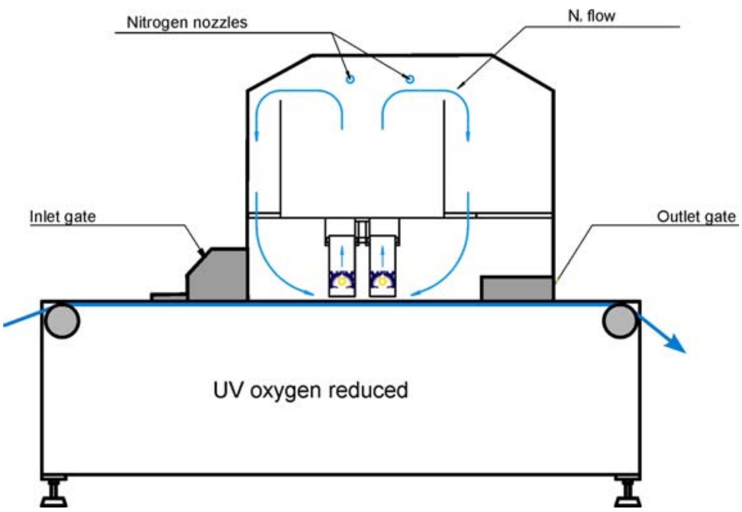

diagram 9: IST-UV-inert circuit system

This process works according to a re-circulating principle using the inert gas both for reaction and for lamp cooling. Here the „cooling gas quantity“ required for lamp cooling capacity is supplied by the inert gas. Nitrogen is driven in a cycle through filtering systems and heat exchangers and is re-circulated. As with closed systems, sealing measures must be chosen for each individual case.

The open system benefits from this design compared to a closed system with a quartz plate:

- The complete lamp radiation area is inerted. Due to the absence of oxygen, no ozone is developed by the UV-radiation.
- The circuit operation with integrated cooling doesn’t produce any exhaust air, i.e. an IST-UV-unit of this generation can be operated without exhaust air independent of lamp numbers
- The system requires that the whole unit is operated with a slight overpressure protecting the unit from taking in ambient dust and dirt particles. The expenditure for maintenance, cleaning, etc. is considerably reduced as pollution can only be caused by the substrate itself or by varnish or ink components.
- The system allows the use of UV-lamps with an increased light penetration in deep UV-areas (UVC) without converting this energy into ozone production or decomposition.

4.4 Air/ water-cooled systems with optional inertisation

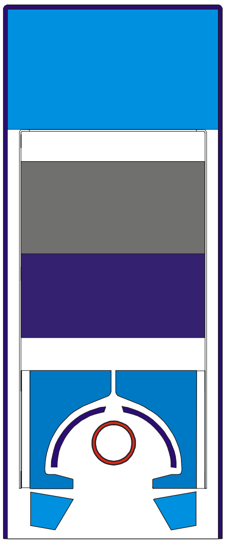

diagram 10: BLK-U®

The BLK-U® System is a further development of the BLK-System with the possibility of an open inertisation requiring extremely small space.
The BLK-U® System has a combined gas-water cooling and can be both operated in normal and in oxygen reduced atmosphere.
This lamp module with integrated, water-cooled shutters and water-cooled reflector is made of extruded aluminium profiles. Each lamp module is enclosed by an additional housing to form an own air cycle. The BLK-U® System
Is designed for outputs of up to 200 W/cm. The water-cooled shutter closes in front of the lamp in case of a stoppage to avoid an overheating of the substrate.
The special features of this module are due to the fact that

- there is almost no air exchange with the ambiency
- no need for exhaust or supply air pipes
- the lamp module can be used at ambient temperatures of up to 150°C

5. UV unit concepts (examples)

Depending on application and space availability the selection of the UV-modules can be configured to design a UV-unit especially tailored for the product of the customer. Now a presentation of some typical, existing, industrial unit concepts will follow. Other unit concepts are certainly possible.

5.1 Varnish curing on headlight lenses

A UV-coating is applied to polycarbonate headlight lenses to improve scratch resistance and to provide an increased resistance to dirt and simplified cleaning. After varnish application and the subsequent evaporation zone the UV-varnish is UV-cured on the headlight lens. In order to expose all edges to UV-light the UV-unit can be divided in two parts and the lens is turned by 90° in the interspace. Each UV-area is equipped with several UV-lamps irradiating the lens from top and from the side. Depending on the geometry of the parts more simplified unit designs might also be possible.

5.2 Varnish curing on reflectors

Before varnishing the plastic surfaces are exposed to light to improve adhesion of the varnish. After varnish application and evaporation zone the UV-varnish is cured with UV-light. The UV-varnish is supposed to create a smooth surface capable of metallization.
After metallization another coating is applied. Here also the use of UV-curable varnishes is possible according to the procedure described above. The reflectors can be

mounted on a chain conveyor. In that case exposure is effected from below by means of UV-modules positioned crosswise.
A further version is the use of cycloid conveyors. Thereby a rotating shaft with a simultaneous feed in a direction x is fitted with several reflectors.

Above this conveyor several UV-modules are arranged crosswise to the direction of passage providing 3-dimensional curing of the parts.

5.3 Varnish curing on dashboards

Dashboards are UV-cured for optical reasons. This method provides a wood-like look. Further on the UV-varnish increases mechanical resistance (e.g. scratch resistance). Also here an evaporation zone is required.

After varnish application and evaporation zone the dashboards pass through a UV-zone with several UV-modules. A possible unit concept might be designed in the following way: several UV-modules are arranged in the direction of passage in an angular adjustable way. In addition, exposure is provided from top by crosswise arranged UV-modules.

5.4 Varnish curing of steel pipes

Steel pipes are UV-varnished for optical reasons in order to achieve a temporary corrosion protection. The application of a pure and solvent-free varnish is followed by curing in a kind of light tunnel. The UV-units are arranged with the lamp axis positioned in the direction of the conveyor passage. The number of lamps depends on the diameter of the pipes. Lamp length is determined according to conveyor speed.

5.5 Varnish curing by means of mobile UV-modules mounted on robots

Especially in the field of varnish curing of three-dimensional components the use of UV-modules mounted on robots is seriously being considered.
The robot can follow up the outlines of the components thus reaching areas which are scarcely accessible in a production line and require an increased number of lamps.
For integration on robots only optimised UV-units are used regarding weight, dimensions and mobility.

6. Outlook on future UV-applications

New developments in raw materials, inks and varnishes open many further possibilities of UV-applications.

- Dual-Cure-Systems with post-curing in an oven or at room temperature (especially for 3D-parts)
- binders with improved adherence on metal
- formulations for outdoor applications
- UV-curing powder

The following UV-applications are therefore possible in future:

- car varnishing in series
- car repair varnishing
- Coil-Coatings
- priming of plastic car body parts
- scratch-resistant varnishing of plastic car body parts
- UV-coatings for metal, plastic and MDF

The development possibilities of UV-technology are not yet exhausted at all. Customers, manufacturers of ink, varnish and raw material, production line manufacturers and UV unit manufacturers can certainly open up further application possibilities in co-operation in order to overcome the still existing restrictions of UV-technology.