NARVA

Information for the applicant

High Pressure Sodium Lamps

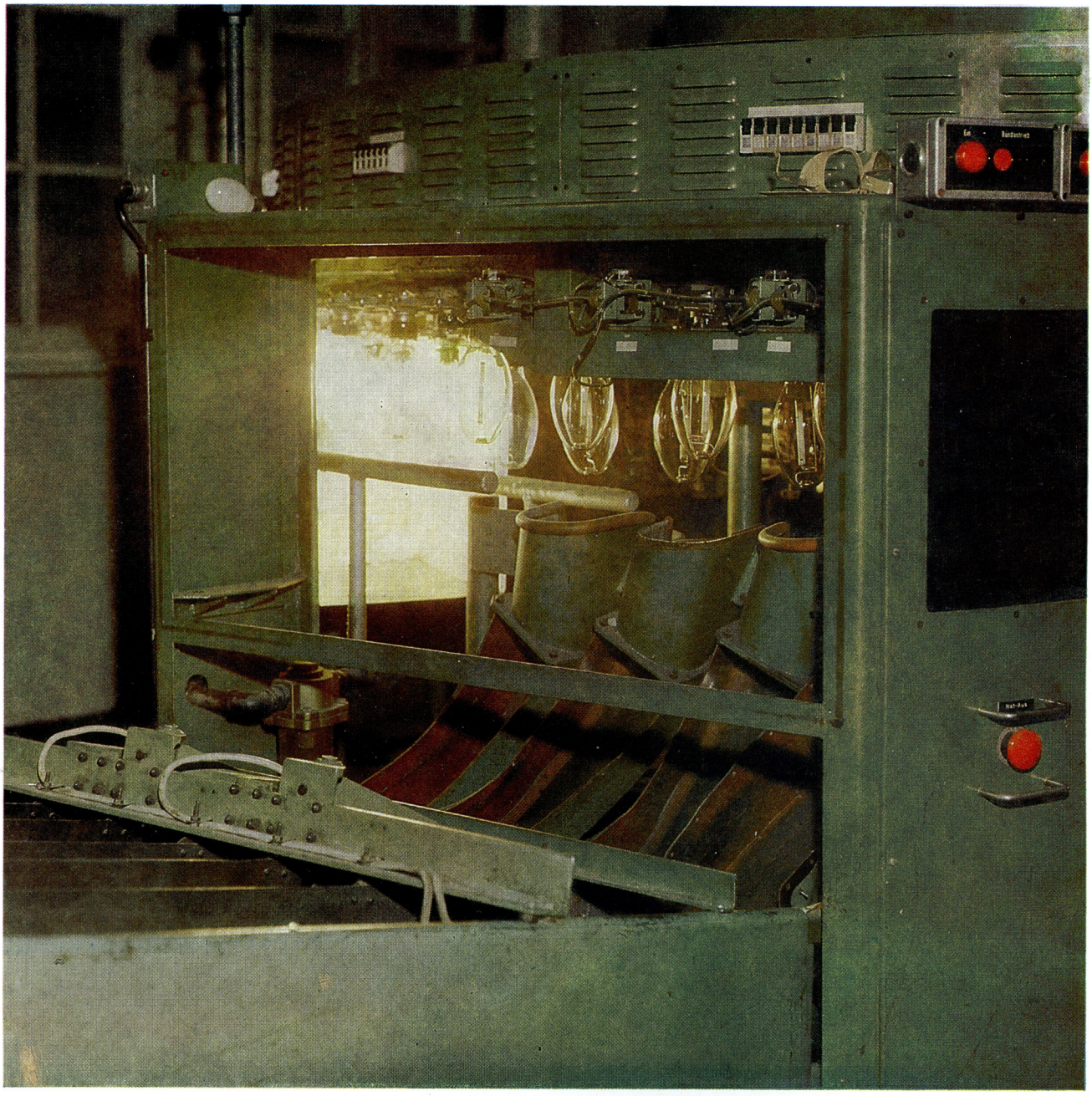
NATRALOX®

the most economical light sources for indoor and outdoor lighting application

1. Introduction

The dictates of the Eighties are to exploit any energy resources we have and to use sparingly the entire energy sources we have now. Particularly in the field of lighting engineering all notable lamp manufacturers endeavour to develop light sources with increasing lumen efficacy.
For this reason high demands are made on the research and development of new technologies and engineering progress. For a reasonable and proper use of such a lamp type developed and produced with great expenditures a special knowledge of the particular lamp type and its field of application is necessary.
We wish to inform you by this instruction and to report on the recently developed lamp type which represents the most economical light source of the Kombinat VEB NARVA „Rosa Luxemburg". According to the

Fig. 1
On-line quality checking of the NATRALOX® lamp type in the factory



factory state of the latest scientific findings as well as investigations on practical use and service a wide range of night pressure sodium lamps produced by our Kombinat is available for lighting engineering of the GDR and foreign countries.
Under the Trade Mark NATRALOX(R) this lamp type is well known and successfully applied in the GDR and many other countries for some years.
The offered range of wattages is reasonably adapted to the application needs of interior and exterior lighting purposes and meets the demands of the international market.
On the base of its favourable data, for instance light output and life time, this lamp type has gained an enormous prestige in the world at very short time.
Simultaneous with many practicabilities in the outdoor lighting application they have prevailed on the field of indoor lighting engineering. The concept of the high intensity discharge lamp fixtures manufactured in the GDR is particularly suited to solve all lighting tasks. Lighting installations with small spot or wide flood light distribution patterns can be designed by supply of different fixture types.
All lighting installations, also such equipped with high pressure sodium lamps, have to meet the specified standard requirements.
For indoor lighting installations it should particularly be observed that adjacent rooms or areas which are mutually used for any reason well-match in respect of the colouration. It means, that the same lamp type should be applied, if possible. In principle, halls and working shops should be equipped with one lamp type only, and so, a replacement of an existing lighting system with high pressure sodium lamps is only reasonable if the entire building or the industrial complex will completely be changed to the new lamp type.

2. Operating instructions and technical data of *NATRALOX* ® lamps

2.1. Construction and operation

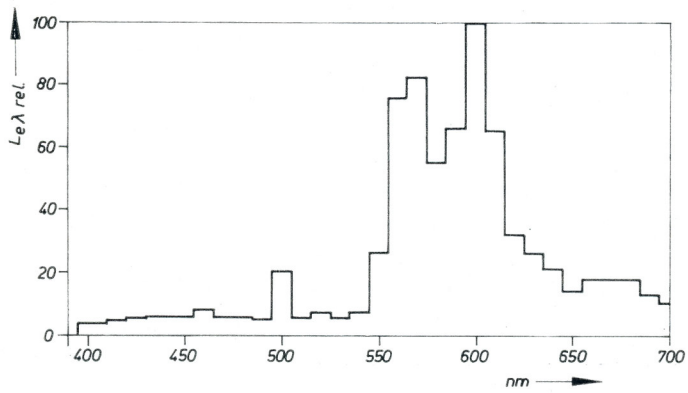
High pressure sodium lamps rank among the high intensity discharge lamps. By its elevated pressure in operation this lamp type emits a broad continuum in a wide range of visible light at high values of light efficacy, i.e. 82 to 120 lm/W for the NATRALOX(R) type.
The appearance of the light is golden yellow.

The essential components of the lamp are the arc tube (burner) and the outer bulb with base.
Because of the use of sodium in the gas discharge a burner tube is required which resists against the sodium attack. For this reason a translucent, polycristalline alumina (Al_2O_3) is applied with a transmission of more than 90 % for the visible light.
The arc tube contains besides sodium, mercury and a rare gas as well as tungsten electrodes.
The discharge operates at approximately 20,000 Pa. The temperature in the centre of the arc tube is about 1200 °C. The correlated colour temperatur is about 2100 K and the general colour rendering index R_a is more than 30. By the broadened emission spectrum all colours of an illuminated object will render satisfactorily at high illumination levels. The colour of the light appears as warm.
Ballasting appliances (choke coil) are applied for limiting of the discharge current. Short-time high-voltage pulses are required for ignition of the lamps. These pulses are produced by use of particular starting appliances.

2.2. Spectral energy distribution

The spectral energy distribution of high pressure sodium lamps depends upon the lamp performance. The coating on the inner surface of the outer bulb results in a light scattering only and does not change the spectral energy distribution.

Fig. 2
Relative spectral energy distribution of a typical high pressure sodium lamp



2.3. Energy balance

The high pressure sodium lamp converts about 29.5 % of the electric input power into visible light. The inside-coating reduces the luminance and effects that the candle power distribution is comparable to this one of other high intensity discharge lamps with coated outer bulb. The luminous flux is a little reduced by the coating compared to the same clear-bulb lamp type.

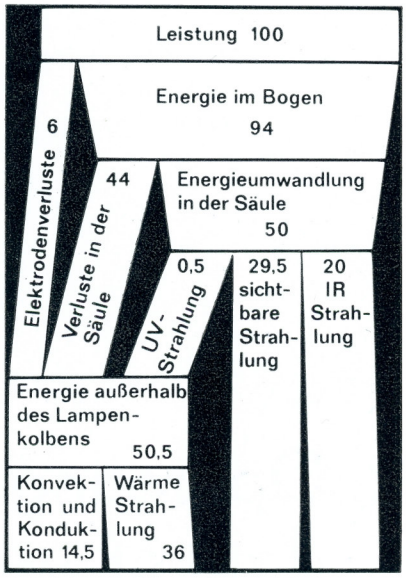


Fig. 3
Energy balance of a typical 400 W high pressure sodium lamp

2.4. Technical data

The lighting characteristics and the dimensions of the NATRALOX(R) lamps are shown in Table I and the electrical ratings in Table II.

Table I

Lighting characteristics and dimensions of NATRALOX® lamps with ellipsoidal outer bulb

Lamp type	Finish	Light output lm	L.C.L.[1] mm	Dimensions mm Ø	Dimensions mm lenght	Burning position	Base
NA 70-00	clear	6000	115 ± 5	75	175	any	E 27 (Medium)
NA 70-01	coated	5800					
NA 175-00	clear	15000	145 ± 5	91	227		E 40 (Mogul)
NA 175-01	coated	14000					
NA 250-00	clear	27000					
NA 250-01	coated	25500					
NA 400-00	clear	48000	184 ± 5	121	283		
NA 400-01	coated	46000					

[1]) Light centre length

Table II

Electrical ratings of *NATRALOX*® lamps with ellipsoidal outer bulb

Lamp type	Wattage W		Rated voltage V	Lamp voltage V	Lamp current A	Initial current (approx.) A
	without ballast	with ballast				
NA 70-00 NA 70-01	70	83	220	90 $^{+10}_{-20}$	1.0	1.4
NA 175-00 NA 175-01	175	198		95 ± 20	2.15	2.8
NA 250-00 NA 250-01	250	278		100 ± 20	3.0	4.0
NA 400-00 NA 400-01	400	435		105 ± 20	4.4	6.0

The life time of the NATRALOX(R) lamp type has been essentially increased in a short time. Started with a life time of 4000 hours for the first generation of high pressure sodium lamps, the useful life has now reached approximately 12,000 hours for the main series of this lamp type. Table III demonstrates the actual state of the lamp life.

Table III

Life time of *NATRALOX*® lamps

Lamp type	Average life h
NA 70-00 NA 70-01	4000
NA 175-00 NA 175-01	8000
NA 250-00 NA 250-01 NA 400-00 NA 400-01	12000

Further investigations on improvements of the life time are being worked continuously, particularly to the lamp types NA 70 and NA 175.

3. Comparison of data with other High Intensity Discharge Lamps

Compared among other high intensity discharge lamps the NATRALOX(R) lamps stands out by their superior light output in respect of the electrical input power, it means, this lamp type provides the highest value of lumen efficacy. Also the life represents a top-value compared to the other lamp types. The values of equivalent wattage types of other high intensity discharge lamps or lamps with nearly the same lumen output will be compared with the high pressure sodium lamp in Table IV.

NAVIFLUX High Pressure Mercury Vapour Lamp			NACHROMA Metal Halide Lamp			NATRALOX High Pressure Sodium Lamp		
Lamp type	Light output lm	Average life h	Lamp type	Light output lm	Average life h	Lamp type	Light output lm	Average life h
NF 125-01	6000	12000	NC 100-00	6300	2000	NA 70-01	5800	4000
NF 250-01	13000		NC 100-01			NA 175-00	15000	8000
NF 400-01	23000		NC 175-00	12000		NA 175-01	14000	
NF 700-01	42000		NC 175-01			NA 250-00	27000	12000
NF 1000-01	57000	6000	NC 250-00	18000	3000	NA 250-01	25500	
			NC 250-01			NA 400-00	48000	
			NC 400-00	30000	4000	NA 400-01	46000	
			NC 400-01					

These features justify the use of high pressure sodium lamps in a wide range of artificial lighting application. Additionally to the reduction of energy consumption some important economical benefits will be obtained:

Reduction of running operation costs by

- reduction of costs for energy consumption
- reduction of costs for replacement and
- extension of maintenance cycles.

The higher investment arising by the required electronic starting circuit will be amortized in no time. Consequently, the demands for a modern and favourable lighting installation can be realized with less electric power and lower costs.

4. Operation characteristics and auxiliaries

According to the particular physical properties the high pressure sodium lamps operates under special operating conditions and needs proper auxiliaries.

4.1. Operation characteristics

The NATRALOX(R) lamp type shows a short warm-up time of about 4 to 5 minutes. During this period they reach at least 80 % of the rated lumen output. The warm-up behaviour and the dependance of lamp parameters upon the applied mains supply voltage are shown in Figs. 4 and 5.

Fig. 4
Warm-up behaviour of a typical high pressure sodium lamp
I_L – Lamp current, ∅ – Light output, t – Time

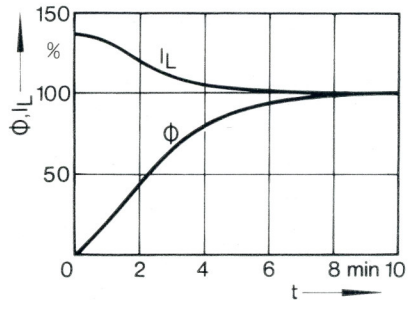
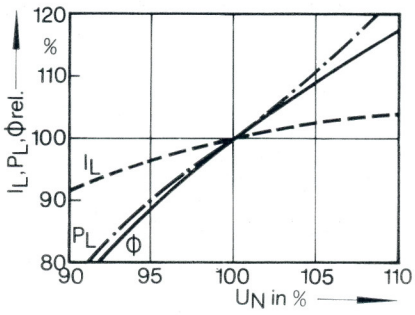


Fig. 5
Lamp characteristics vs. applied mains supply voltage
I_L – Lamp current, P_L – Lamp wattage, ∅ – Light output, U_N – Mains supply voltage



Besides the dependance of the lamp current, lamp wattage and light output upon the mains voltage and in the case of over and under voltage, respectively, the lamp life will be negatively affected. Moreover, the colour temperature will be changed. The restart time is about 1 to 2 minutes.

4.2. Auxiliaries

Special designed ballasts according to the technical data of the particular wattage type are required. These ballast types are designed for the mains supply voltage 220 ± 11 V and the frequency of 50 Hz.

The electrical data of this ballast type manufactured by VEB NARVA Elektrobetrieb Weida are shown in Table V.

Table V

Technical data of ballast types for *NATRALOX*® lamps

Ballast type	Suited for lamp type W	Mains voltage V	Operating current A	Approx. power loss W	Mass kg
VNHD 70	70	220	0.985	13.0	2.0
VNHD 175	175		2.15	23.0	3.9
VNHD 250	250		3.00	28.0	5.8
VNHD 400	400		4.40	35.0	7.3

Proper starting circuits are required for a reliable ignition of the lamp. These devices are manufactured and offered by VEB NARVA Elektrobetrieb Weida.

For normal operation thyristor starters should be applied. They should be installed close to the lamp on the reason of the maximum permitted length of the starting cable. The length of this starting cable depends on the permissible load capacity of the starting device. This capacity should not exceed 200 pF to Neutral and earth, respectively. Therefore, the maximum length of the starting cable is approximately 2000 mm.

The starting cable must be installed so that it is connected to the bottom contact of the base. If for any reason the starting device must be installed remotely than electronic glow switch starters must be used. This type of starter may be installed up to 80 m remote of the lamp operated by it. The available starters produced by VEB NARVA are shown in Table VI.

Table VI

Data of starting devices for *NATRALOX*® lamps

Starter type	Auxiliary part	Permissible ambient temperature	Degree of protection
Electronic thyristor starter ThZ 70	—	–20 . . . +60 °C	IP 00
Electronic thyristor starter ThZ 175-400	—	–20 . . . +60/80 °C [1]	IP 00 [2]
Electronic starter HQZ 400	Glow-switch starter St H 101	–20 . . . +60 °C	IP 54

[1] 60 °C direct in the starting process
80 °C for operating the burning lamp

[2] IP 54 being prepared

The circuit of high pressure sodium lamps with thyristor starter is illustrated in Fig. 6, the circuit with electronic glow switch starter in Fig. 7.

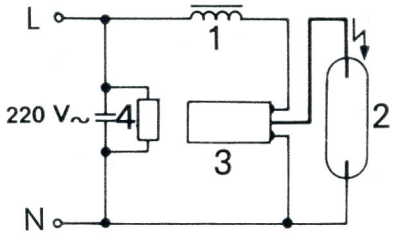


Fig. 6
Circuit for high pressure sodium lamps with thyristor starter in single compensation

1 – Ballast suited with the lamp type
2 – Lamp
3 – Thyristor starter MhZ suited with the lamp type
4 – P.f. correcting capacitor with shunt

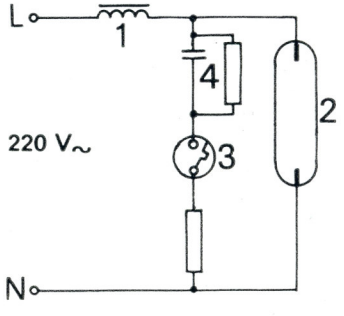


Fig. 7
Circuit for high pressure sodium lamps with electronic glow-switch starter HQZ 400

1 – Electronic starter HQZ 400
2 – Lamp
3 – Glow-switch starter St H 101
4 – Current limiting capacitor for the starter and shunt

As the other high intensity discharge lamps the high pressure sodium lamps are operated with a lagging reactance ballast.

This mode of operation results in a lagging reactance current in the power supply network. For compensation of this lagging current up to a power factor cos $\varphi > 0.90$ correcting capacitors are required, as shown in Table VII.

Table VII

Required correcting capacitors for *NATRALOX*® lamps

Lamp type	cos φ		Required correcting capacitor φ F
	non-compensated	compensated	
NA 70	0.37	0.90	10/220 V
NA 175	0.41	0.97	25/220 V
NA 250	0.42	0.94	33/220 V
NA 400	0.45	0.97	50/220 V

Besides the single compensation also the group or central compensation can be applied. The required data can be calculated from the given and the desired factor under consideration of the power to be corrected.

5. Project engineering of lighting installations with High Pressure Sodium Lamps

The high pressure sodium lamp represents the most economical light source in respect of energy consumption as well as costs. Therefore, the field of application for high pressure sodium lamps is continuously extending.

The selection of a suited lamp type must be made primarily in respect of the light efficacy, and so the high pressure sodium lamp ranks at the first place among the other light sources. Than, in the second place, should be decided from the view point of colour rendering properties, colour, lumen per light point and other requirements which lamp type should be used.

The most important colours for the general safety requirements are good-rendered, only the yellow hue appears over-emphasized.

For indoor lighting projects the architectural and building particularities should be included in the lighting installation. For this reason the colouration of a room or building should be matched with the high pressure sodium light.

Just before it has been pointed out that rooms which are often and mutually used should be illuminated by lamps with the same appearance and colour.

The remote arrangement of ballasts and starting devices inside of the column base or a separate box on the ground has successfully been proved for floodlight installations.

Generally, a mixing of any kind of light with the light from another lamp type should be avoided in the layout and installation of lighting equipment, but only the light of high pressure sodium lamps may be combined with incandescent or fluorescent lamp light of the "warm white" type, particularly for special working place lighting purposes.

Just as all other types of discharge lamps the connection of adjacent lamps to different phases of the three-phase mains supply is required in order to avoid the stroboscopic effect.

The calculation of the required number of lamps and luminaires is determined by the application criteria. This may be estimated or calculated according to the known 'lumen output' method in the case of indoor lighting application and medium illumination levels. If a defined illumination level is demanded for certain working places than the 'candle power' method should be used.

For outdoor lighting application as well as open area floodlighting, principally, the 'candle power' method must be used.

For evaluation of street lighting systems certain methods for determining of illuminance or derived methods should be applied.

6. Economical estimation and recommendations

for re-installation of a lighting system with high pressure sodium lamps

An economical approach on application of high pressure sodium lamps depends on some variables. However, these variables are hard to estimate and never in large-scale. Therefore, particular investigations are required but in any case savings in energy and costs for electricity will be obtained.
In the case of new-installation only the quality and feature of the appropriate lighting installation should be considered.
The replacement of the at present mostly-used high pressure mercury vapour lamps by high pressure sodium lamps of nearly the same lumen output is the dominant procedure of re-installation in an existing lighting system, mainly for street lighting re-installations. Otherwise, it should be estimated for indoor lighting installations designed for relatively large ground areas, e.g. workshops, whether lamps with the same input power under reduction of the number of luminaires should be installed or not. This will primarily be determined by the required uniformity of illumination.
The running operation costs are the major portion of the economical evaluation of a lighting installation and, in that, the energy costs represent the principal proportion.
In general, the following comparison may be made regarding the energy costs in the case of indoor lighting installation:

For lighting of a hall by downlighters equipped with the high pressure mercury vapour lamp type NF 400-01 (system 1) exactly 30 luminaires are necessary for reaching a general illuminance $E_n = 300$ lx on a ground area of 1000 m^2.
Now, two lighting installations are compared:
one installation equipped with the same number of luminaires but the lamp type NA 250-01 (system 2) and the other one equipped with high pressure sodium lamps of the same wattage but a reduced number of luminaires (system 3).

Lighting system	1	2	3
Lamp	NF 400-01	NA 250-01	NA 400-01
Light output per lamp in lm	23,000	25,500	46,000
Number of luminaires	30	30	15
Input power per lamp in W	426	278	435
Total input power in kW	12.78	8.34	6.525
Energy consumption at 2500 operating hours per year in kWh	31,950	20,850	16,313
Energy costs per year at an energy rate of 0.20 M/kWh in M	6,390.00	4,170.00	3,262.00
Relative evaluation in %	100.0	65.3	51.1
Absolute savings per year compared with lighting system 1			
in kWh	–	11,100	15,637
in M	–	2,200.00	3,127.40

The more operating hours per year and the higher the rate of energy costs the more savings in energy consumption and energy costs. As to see from this example the greatest savings (approximately 50 %) will be obtained by reducing the number of fixtures and replacement of high pressure mercury lamps by the high pressure sodium lamp type of the same wattage.

7. Demonstrations of lighting installations with the High Pressure Sodium Lamp *NATRALOX®*

The high-efficient high pressure sodium lamps have been firstly introduced in the range of application where economic dominates but the colour rendering is only the second choice. Primarily, this is actual for public lighting.

The well-aimed use of high pressure sodium lamps in this field has been realized since several years and it was promoted by the following favourable factors: –

- The usual heights of lighting columns were particularly suited for application of high pressure sodium lamps
- The entire street lighting engineering of the GDR has been principally used the high pressure discharge lamp type, and so a great deal of experience in application of this lamp group has been accumulated
- A replacement of high pressure mercury vapour lamps by high pressure sodium lamps was possible often with little expenses only.

The application of high pressure sodium lamps for indoor lighting problems has been recently pushed forward.

Outdoor lighting installation

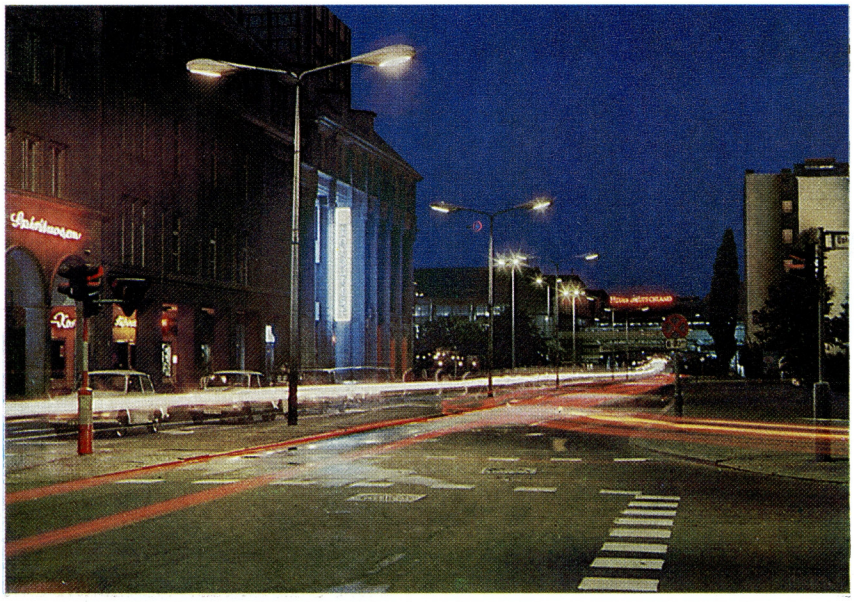
Street lighting installation 'Unter den Linden' in Berlin

The main street 'Unter den Linden' is designed as a twin-lane roadway from the memorial 'Brandenburger Tor' to the opera house 'Staatsoper'. Between these two lanes a pedestrian area is located separated from the lanes by two rows of linden-trees at both sides. Lanes and pedestrian area are separately illuminated in respect of the specific requirements of each one.

The roadways are illuminated by side-entry fixtures mounted on steel columns with a light centre height of 9.5 m (two NA 175-01 lamps, each) shown in Fig. 8.

Fig. 9 demonstrates the pedestrian area illuminated by pole-mounted post-top fixtures equipped with high pressure sodium lamps NA 70-01. The fixtures are mounted on steel poles of a height of 3.5 m staggered on both sides.

The street crossing 'Unter den Linden/Friedrichstraße' is illuminated by two five-arm lighting columns of about 16 m in height (NA 400-01), By the Figs. 10 and 11 is clearly demonstrated that all lighting columns are equipped with the well-matching high pressure sodium lamp type. The lighting installation consists of twin-bracket steel columns of 8 m in height located at the dividing strip of the twin-lane roadway. The fixtures are equipped with two NA 175-01 lamps per luminaire.



The lighting of the parking lots at the 'Berliner Ostbahnhof' is provided by three 24 m columns equipped with rectangular mounting supports. Twelve fixtures with one NA 400-01 lamp are arranged on the top of the column (Fig. 12). The station building itself is also illuminated by this lighting system and exhibited by its high illuminance.

The Figs. 13 to 15 show a beautiful solution of an architectural arrangement between modern buildings and on old-fashioned borough of Berlin – the 'Spittelmarkt'. The lighting of the separated pedestrian area was designed by means of old-fashioned style lanterns in the original performance of K. F. Schinkel, a famous German architect of the 18./19. Century. The posts, also designed in respect of the history, are 3 m in height and the style lanterns are equipped with one NA 70-01 lamp.

The lighting project of the street 'Leninallee' in the county town Halle/Saale is performed as high column installation of 24 m in height. Each column is provided with 12 side-entry fixtures equipped with the high pressure sodium lamp type NA 400-01. Figs. 16 and 17 demonstrate this lighting installation seen from the same view point, firstly in direction to the highway and than in the opposite direction.

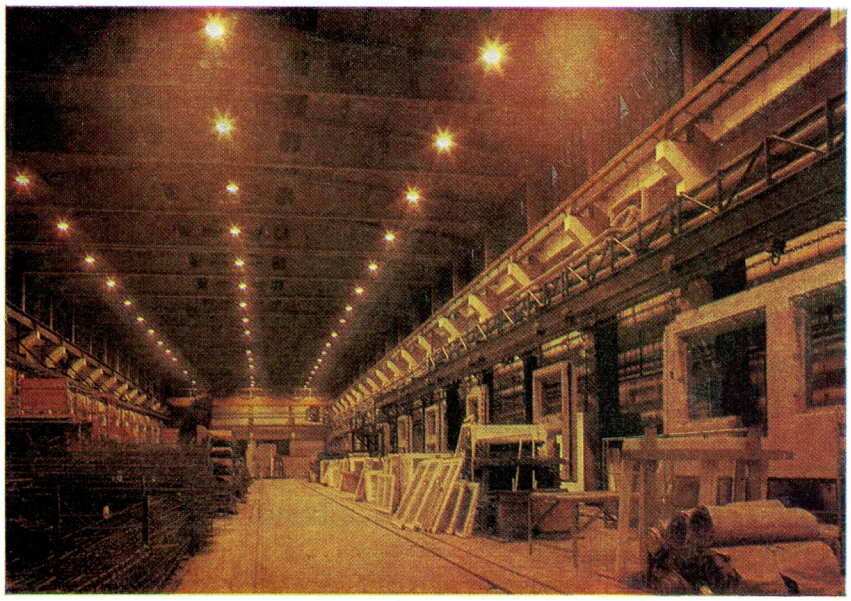
Moreover, the county town Halle has an imposing traffic-free zone ending in the historical market-place. This borough is illuminated by means of post-top fixtures with the NA 175-01 lamp type. The fixtures are arranged in groups of 18 units mounted on the top of steel posts of 8 m in height (Fig. 18).

Indoor lighting installations

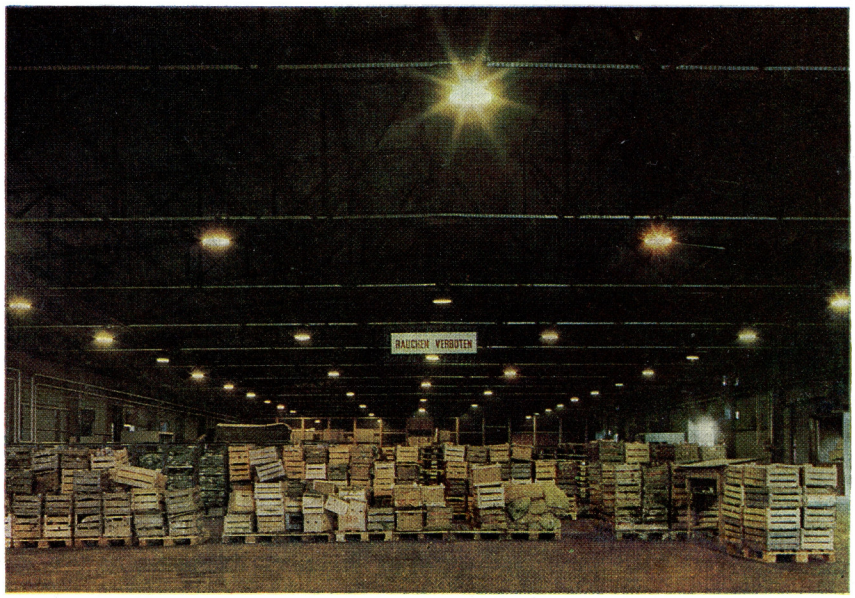
The high pressure sodium lamp is suited for indoor lighting application in large rooms and halls with ceiling heights of about 6 m or more. By use of this smaller lamp type NA 70-01 is it possible to obtain lower lumen output concentrations per light centre. This meets the requirements of uniformity of the illumination distribution pattern in the case of lower values of average illumination.

Fig. 19 shows the lighting of a motorcar repair shop by use of 9 high pressure sodium lamps NA 250-01 mounted in wide flood downlighters. By arrangement of these lamps in the same light centre height of 6 m an average illumination level of about 480 lx is obtained. The colour of the high pressure sodium light should by taken into account and should, moreover, well match with the supplementary lighting which should be provided with an appropriate lamp type. For instance, work tables are often provided with supplementary luminaires equipped with the fluorescent lamp type "warm white" and portable fittings with incandescent lamps.

The lighting of a factory producing components for building engineering by use of high pressure sodium lamps results in enormous economical benefits. The demands concerning the colour rendering are of low-grade, therefore, the downlighters are equipped with NA 250-01 and arranged for a light centre height of approximately 10 m. An average illumination level of 400 lx is obtained accompanied by a good uniformity, as seen in the Fig. 20.



Furthermore, the lighting of storage houses by use of high pressure sodium lamps is one of the most favourable solutions in respect of lighting economy. Fig. 21 shows a storage hall for fruits and vegetables of a wholesale business in Berlin which is illuminated by the high pressure sodium lamp type NA 175-01.



The models of high pressure sodium lighting installations as here demonstrated are only a small choice of practicabilities and facilities in the wide field of application of this economically outstanding lamp type. In order to save energy as well as costs the use of these lamps should be really taken into account for lighting of industrial plants, roadways and other outdoor applications.
NARVA will you give assistance to solve your lighting problems by use of our products and technical Know-how.

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