

THE NEW ELECTRICAL SYSTEM OF THE GROTTA GIGANTE: COMPLIANCE WITH THE LAWS IN FORCE AND LIGHTING STUDY THE GROTTA GIGANTE AS A TOURIST AND SCIENTIFIC CENTRE

Alessio Fabbriatore

*Grotta Gigante, Società Alpina delle Giulie – sezione di Trieste del Club Alpino Italiano,
Borgo Grotta Gigante 42/A, I-34010 Sgonico (TS), Italy*

Abstract: The *Grotta Gigante*, which opens into the Mesozoic limestone, is a large cave, and the only one to be open to the public among the caves of the Trieste Karst and it has always been an object of scientific study. The important union of tourism and scientific research made it possible for the *Grotta Gigante* to be constantly monitored in order to ensure ecocompatibility between the flow of tourists and the delicate underground environment of the cave.

In December 2005 the new *Visitors reception centre of the Grotta Gigante* was inaugurated: a multipurpose building which blends in with the surrounding karstic environment. It was deemed necessary to replace the electrical and lighting systems, in accordance with the laws in force, and to ensure the cave's full compliance with safety measures. These measures were taken in order to ensure the safety of both the staff and the visitors, as well as to enhance the natural beauty of the *Grotta Gigante*, thanks to an appropriate lighting system.

The new electrical system takes into account the reduction of operating costs, by reducing energy consumption, and at the same time the importance of the spectacular effect, by emphasizing the concretions and natural colours of the cave. The paths open to the public are provided with luminous bodies fitted to special supports for emergency and safety lighting and these emergency lamps are connected to a specific uninterruptible power supply exclusively dedicated to this circuit.

A new audio system was installed and a radio transmission network (Motorola), provided with an auxiliary relay, was chosen, in order to be able to communicate from anywhere inside the cave with the external operator or vice versa.

Keywords: Karst, Grotta Gigante, Trieste, giant cave, pendulums

The *Grotta Gigante* (Jama v Briščikih – Riesengrotte) is situated in the municipality of Sgonico, province of Trieste, in north-east Italy: lat 45° 42' 34" Nord-long 13° 45' 54" East.

The *Grotta Gigante*, which opens into the Mesozoic limestone, is a large cave, and the only one to be open to the public among the caves of the Trieste Karst. Its central cave entered the Guinness Book of Records in 1995 as the largest show cave in the world. The cave is 107 metres high and 130 metres wide, and has a volume of 600,000 m³. The first documented mention of the *Grotta Gigante* dates back to 1851. The *Grotta* was opened to the public in 1908 by the Club Touristi Triestini (Trieste tourist club). Due to the new political

climate, in 1922 the *Club turisti triestini* was forced to sell the *Grotta Gigante* to the *Società Alpina delle Giulie sezione di Trieste del Club alpino italiano* (The Julian Alps Association, division of Trieste of the Italian Alpine Club). At that time the *Società Alpina delle Giulie* also came into possession of other caves in the province of Trieste, which used to belong to the Alpenverein and the Planinsko Društvo (*San Canziano, Corgnale, Sottocorona, Grotta del fumo*).

After the Second World War, the *Commissione Grotte Eugenio Boegan* (Eugenio Boegan Cave Commission) of the *Società Alpina delle Giulie* took charge of the *Grotta Gigante*. The structure was reinforced and a new acetylene lighting system was installed.



Fig. 1. The new Visitors reception centre of the Grotta Gigante. Photo: A. Fabbriatore



Fig. 2. The new Visitors reception centre of the Grotta Gigante by night. Photo: A. Fabbriatore

Between 1957 and 1963 two buildings were built, one for the ticket office and the other for the Speleological Museum, the first museum of this kind in Italy. Thanks to substantial modernization and maintenance work, which was concluded in 1996, the number of visitors increased considerably, reaching 70,000 – 80,000 visitors per year, with a few peaks of 100,000 annual visitors.

Later on, in December 2005, the new *Visitors reception centre of the Grotta Gigante* was inaugurated, a multipurpose building which blends in with the surrounding karstic environment.

The Grotta Gigante, with its seventy thousand annual visitors, is the second tourist centre in the province of Trieste and one of the first in the Friuli Venezia Giulia region.

Almost half of the seventy thousand annual visitors consists of students from schools of

all kinds and levels, from preschool to university, for whom special educational programmes have been conceived in order for them to make the most of their visit to the *Grotta Gigante*.

The *Grotta Gigante* is a very important centre of scientific research. Inside the cave, *pendulums*, i.e. sensitive instruments able to detect the movements of the earth's crust, were installed. The *pendulums* provide a unique historical series of continuous measurements of the deformation of the earth's crust. These measurements are carried out by the *Department of Earth Sciences of the University of Trieste* and the *National Institute of Geophysics and Volcanology*. Inside the

cave you can also find the digital, broad band *Seismographic Station* run by the *National Institute of Oceanography and Experimental Geophysics* and the *Department of Geosciences of the University of Trieste*, thanks to a cooperation agreement. Outside the *Grotta Gigante*, in the surrounding green area, you can find the *Climatological Observatory of the Karst* and the *Epigeal station for the measurement of karstic dissolution*.

The *Climatological Observatory of the Karst*, which has been operating since 1966, is part of the regional meteorological network of Friuli Venezia Giulia and the Trans-European network. The traditional mechanical instruments have been complemented by a new-generation, electronic meteorological station equipped with GPRS data transmission and real time data display on the Web and on the maxi screen in the waiting room of the *Visitors reception centre*.

The *Epigeian station for the measurement of karsitic dissolution*, which has been operating since 1979, investigates the extent of the lowering of calcareous rock surfaces due to meteoric water. Measurements are taken in accordance with the *Department of Geosciences of the University of Trieste*.

It is also worth mentioning the studies concerning *radiography*, by means of cosmic rays, for the *Chooz experiment*, which a *Muon radiography* of the *Grotta Gigante* made it possible, i.e. the reconstruction of the shape of the cave's vault from the measurements of the flow of cosmic rays coming from various directions, which were compared with available geological data. The radiography was carried out thanks to the collaboration between the *National Institute of Oceanography and Experimental Geophysics* and the *National Institute of Nuclear Physics*.

We should not forget the archaeological studies carried out by the *Environmental, Architectural, Archaeological, Artistic and Historical Heritage Office* of the Friuli Venezia Giulia region and by the *Dipartimento di Storia e Culture dall'antichità al Mondo Contemporaneo of the University of Trieste*. They show that the cave was used from the Neolithic Age to the Early or Middle Bronze Age, the palaeontological studies carried out by the *Municipal Natural History Museum of Trieste* and the biology stations (underground fauna and flora, i.e. *Lampenflora*), thanks to the collaboration between the *Municipal Natural History Museum* and the *University of Trieste*.

The *Agenzia regionale per la protezione dell'ambiente (Regional agency for the protection of the environment)*, with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report which includes the results of the measurements taken on the tourist pathway. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree".

The important union of tourism and scientific research made it possible for the *Grotta Gigante* to be constantly monitored in order to ensure ecocompatibility between the flow of tourists and the delicate underground environment of the cave.

Radon monitoring. The *Agenzia regionale per la protezione dell'ambiente (Regional agency for the protection of the environment)*, with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report which includes the results of the measurements taken on the tourist pathway. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree".

THE NEW ELECTRICAL SYSTEM OF THE GROTTA GIGANTE: COMPLIANCE WITH THE LAWS IN FORCE AND LIGHTING STUDY (PROJECT BY ARCHITECT ALESSIO FABBRICATORE)

In December 2005, the new *Visitors reception centre of the Grotta Gigante* was inaugurated and it was deemed necessary to replace the electrical and lighting systems, in accordance with the laws in force, and to ensure the cave's full compliance with safety measures for the following reasons: due to the tourism potential of the *Grotta Gigante*, which has become a fixed point of reference for tourists visiting Trieste and its surroundings and an important attraction for the many tourist groups, both Italian and foreign, visiting the region; and due to the cultural value of the cave, attested by the trips organised by schools of all kinds and levels coming from all over Italy.

These measures were taken in order to ensure the safety of both the staff and the visitors of the cave, as well as to enhance the natural beauty of the Grotta Gigante, thanks to an appropriate lighting system

It is to note that the first electrical lighting system was carried out in 1957 by the *Società alpina delle Giulie sezione di Trieste del Club Alpino Italiano (The Julian Alps Association – division of Trieste of the Italian Alpine Club)* and the cave's original carbide lamps were replaced by an electrical lighting system

Environmental and safety measures

During the work in 2009 for the replacement of the electrical system to comply with the laws in force and to make the existing handrail in the *Grotta Gigante* safe, all the

unused and polluting (non-inert) materials, which had been deposited at the bottom of the cave since it was opened to the public 100 years ago, were cleared and taken to the municipal rubbish dump. This waste mainly consisted of maintenance materials which had not been disposed of, such as the synthetic sheaths covering the pendulum cables (which were deposited at the bottom of the cave), but also of highly polluting wooden elements in the cave (wood causes the development of bacteria and insects, of external origin, which would otherwise not be able to develop). All potentially polluting materials were therefore removed from the *Grotta Gigante*.

As far as staff safety is concerned (guides and administrative staff), a *Document for risk evaluation* was drawn up for the employees of the Società Alpina delle Giulie, owner of the *Grotta Gigante*, and a safety manager was appointed. The *Agenzia regionale per la protezione dell'ambiente* (Regional agency for the protection of the environment), with reference to the measurements of radon in the *Grotta Gigante*, in compliance with legislative decree no. 241/00, drew up the final technical report which includes the results of the measurements taken on the tourist pathway. According to this report "the action level does not exceed the limits fixed by the above-mentioned decree".

General features of the electrical system

The existing electrical power supply is *Low Tension*; with reference to the neutral state, the system is a TT, three-phase, 400 V, 50 Hz system, with a subscribed demand of 70 kW. The origin of the electrical installation is slightly downstream of the electrical power supply point of the distributing company (ENEL), inside a concrete box near the cave's entrance. Inside this box you can also find the utility main switch equipped with an emergency release coil, to which the main riser, which consists of FG7 cables, is connected, and takes up to the main utility switchboard, which is located in a special technical room in the basement of the *Visitors reception centre of the Grotta Gigante*. This switchboard is equipped with special protections for the entire electrical system, which is divided into two main areas, one for the circuits relating

to the *Visitors reception centre* and the other one for the circuits relating to the cave. The electrical system is entirely protected by an uninterruptible power supply, always *on-line*, located next to the main switchboard in the same room. It is also protected by a diesel generating set, in a separate room, for emergency use in the event of unavoidable malfunctioning or black-outs of the system. The earthing system consists of a 50 mm²-section bare copper wire connected to the reinforcing bars of the foundation plinths of the *Visitors reception centre* building. This wire is connected to the main earthing terminal within the main utility switchboard, from which the various protective conductors, with the same section as phase conductors, are distributed to the circuits.

Replacement of the electrical system

The former electrical system inside the cave was the result of all sorts of work, with no overall plan, carried out to satisfy the needs that had occurred over the years. The functioning of the system was guaranteed by ordinary and extraordinary maintenance operations.

The above-mentioned electrical system was divided into four parts:

1. regular lighting;
2. emergency lighting provided with self-powered lamps and generating set for regular lighting;
3. utility outlets;
4. signalling systems for staff communication.

The former electrical system did not comply with the law and, what is more, was obsolete in terms of energy saving and lighting performance, which made it extremely difficult for the visitors to appreciate the special features of the cave, with a consequent loss of interest on their part.

The new electrical system takes into account the reduction of operating costs, by reducing energy consumption, and at the same time the importance of the spectacular effect, by emphasizing the concretions and natural colours of the cave.

On the occasion of the building of the new *Visitors reception centre of the Grotta Gigante*, and upon request for an increase in the power

supply (70 kW), the Società Alpina delle Giulie disposed of the existing generating set, which was no longer reliable, and bought a new one with appropriate electrical features (50 kVA), in order to coordinate its functioning with the new uninterruptible power supply. The combined functioning of these two equipments enables the entire electrical system (in the cave and the *Visitors reception centre*), except for the conditioning system in the *Visitors centre*, to continue working under any conditions, preventing any interruption in power supply. This operation also aimed at protecting the scientific equipment inside the cave, used by the University of Trieste (pendulums) and by the Experimental Geophysics Observatory (seismograph), and outside the *Visitors centre* (meteorological station).

Upon request for the official certification of the earthing system (in compliance with the laws in force) to the A.S.S. of Trieste (the Local Health Authority), and in particular to the *Servizio verifiche periodiche* (*Periodical check service*), an inspection of the system was made by the person in charge, who drew up a report stating that, as regards the use of the *Grotta Gigante* for guided tours and art shows and the use of the other *premises*, it is a "...place of public show and entertainment in compliance with the IEC regulation no. 64-8/7, paragraph 752.2."

As a consequence, the criteria for the replacement of the above-mentioned electrical system were defined and the following operations were carried out:

a) Exactly defining and renaming the devices relating to the circuit of the cave within the Switchboard of the *Visitors Reception Centre*, in order to be able to identify the relative downstream circuits.

b) Checking the mechanical and electrical features of the existing main supply cable (riser), and measuring the isolation voltage, referring to its junction box as well. The above-mentioned riser is a multicore cable with a 70 mm²-section, ensuring the voltage drop maximum value, which is 4 %, it has a 380 V voltage and supplies power to the newly-installed section switchboards.

c) Installing the section switchboards (Q1, ..., Q6), which consist of watertight boxes, suitable for their laying position and for housing the

protection devices of the various downstream circuits and of the terminal boards for the branch connection from the main riser.

d) Installing different types of luminous bodies, with different optics according to the *object* or the *scene* to be lit up, provided with lamps characterized by different power and colour temperature in order to emphasize the natural beauty of the cave.

Description of the luminous bodies

1. *Double insulated symmetric rhodium 3* (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: symmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests - 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm² section. 2P+T terminal board with a maximum conductor section of 4 mm². Equipment: silicone rubber gasket. Fibreglass nylon cable gland, ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 - IEC 34 - 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. *Master CityWhite CDO-TT* metal halide discharge lamp with E40 fitting, colour temperature 2,800 K.

2. *Double insulated asymmetric rhodium 3* (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: asymmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests - 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with

silver contacts. Wiring: 230V/50Hz supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm² section. 2P+T terminal board with a maximum conductor section of 4 mm². Equipment: silicone rubber gasket. Fibreglass nylon cable gland. ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 - IEC 34 - 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. Master CityWhite CDO-TT metal halide discharge lamp with E40 fitting, colour temperature 2,800 K.

3. *Maxiwoody (iGuzzini)*. Pressure die-cast aluminium floodlight, coated with liquid acrylic paint. Super-pure aluminium reflector. MasterColour CDM-T 250W discharge lamp, with E40 fitting, colour temperature 3,000 K. Spot light distribution (*spot optics*). The floodlight can be adjusted vertically by means of a painted steel bracket, provided with a graduated scale with a 10° pitch and with mechanical locking devices which ensure the correct orientation of the light beam, and horizontally by means of a hot-dip galvanized painted plate to fix it to the ground. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP67 IK08. F mark. IMQ-ENEC certification. IMQ Performance. Protection class II.

4. *Platea (iGuzzini)* 10° super-spot aluminium floodlight. Super-pure aluminium reflector. 10° super-spot optics. 250 W power supply, Osram Powerball HCI-T metal halide discharge lamp with E40 fitting, colour temperature 3,000 K. Stainless steel screws. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66 IK04/08. F mark. IMQ-ENEC certification. IMQ Performance. Protection class II. The appliance complies with the requirements of the UNI 10819 regulations, zone 1 (light pollution).

5. *Miniwoody (iGuzzini)*. Floodlight with base and built-in electronic power supply. Designed for the use of discharge light sources.

Composed of an optical unit and a support. Aluminium alloy optical unit, arm, base and frame. Optical unit connected to the components' unit by means of a silicone armoured cable with protection steel plait. M14X1 nickel-plated brass cable gland connecting the wiring unit to the lamp unit. Reflector made of annealed 99.96 % super-pure aluminium sheet, which underwent roughening, polishing and 2/4 micron electrochemical anodization treatment. Spot optics and surface partly painted in black. Lamp holder support made of galvanized steel. Polyamide PG11 cable gland. Electronic power supply, MasterColour CDM-Tm Mini 20W metal halide lamp with PGJ5 fitting, colour temperature 3,000 K. Openings on frame for rainwater discharge. All screws are made of A2 stainless steel. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66 IK08. F mark. IMQ-ENEC certification. IMQ Performance. Protection class I.

6. *Woody (iGuzzini)*. Aluminium alloy optical unit and frame. EN1706AC 46100LF treated with phosphochromatising, double primer, passivation at 120 °C, coated with liquid acrylic paint highly weather- and UV-resistant, baking at 150 °C; spot optics; soda-lime tempered glass cover, transparent, colourless, 4 mm thick, fixed with captive screws; stainless steel safety cable; reflector made of annealed 99.98 % super-pure aluminium sheet, which underwent roughening, polishing and 2-4 micron anodization treatment with a nickel salt fixing bath; aluminium lamp holder support; openings on frame for rainwater discharge; PG11 nickel-plated brass cable gland. Removable component tray, made of hot-dip galvanized EN10142 DX 51D+Z(ZF) steel sheet, which underwent roughening treatment; box and cover in painted EN1706AC 46100LF aluminium alloy; spacers and captive screws; power supply unit provided with anti-explosion power factor correction capacitor, ballast, igniter and fast-connecting terminals. All screws are made of A2 stainless steel. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66 IK07. F mark. IMQ-ENEC certification. IMQ Performance. Protection class II. MasterColour CDM-T 70W discharge lamp with G12 fitting, colour temperature 3,000 K.

7. *Double insulated symmetric rhodium 2* (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: symmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests - 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz power supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm² section. 2P+T terminal board with a maximum conductor section of 4 mm². Equipment: silicone rubber gasket. Fibreglass nylon cable gland, ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 - IEC 34 - 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. MasterColour metal halide discharge lamp with Rx7s fitting, colour temperature 3,000.

8. *Double insulated asymmetric rhodium 2* (HPS-T 250W). Body without frame: in pressure die-cast aluminium, with cooling fin. Reflector: asymmetric, in hammered 99.85 aluminium, anodized, 3-micron thick and polished. Diffuser: 5 mm tempered glass, thermal shock and impact resistant (UNI EN 12150 tests - 1:2001). Coating: polyester powder painting in graphite grey, corrosion and salt spray resistant. Lamp holder: in ceramic with silver contacts. Wiring: 230V/50Hz power supply with thermal protection. Flexible wire with tinned brass terminals, insulated with fibreglass braid, 1 mm² section. 2P+T terminal board with a maximum conductor section of 4 mm². Equipment: silicone rubber gasket. Fibreglass nylon cable gland, ½ inch gas diameter. Anticorrosion and antiseizing steel captive screws. Steel bracket with protractor scale. The front glass opens on hinges without the use of tools and stays attached to the body of the appliance. Provided with air recirculation

valve. Locking devices in AISA316L steel with safety screw. Regulations: produced in compliance with the EN60598 - IEC 34 - 21 regulations. Degree of protection in compliance with the EN60529 regulations. HPS-T 250W. MasterColour metal halide discharge lamp with Rx7s fitting, colour temperature 3,000.

e) The luminous bodies are fitted to special supports for emergency and safety lighting of all the cave's pathways open to the public and are on "always ON" mode, thereby ensuring a minimum light of 5 lux on the steps and 3 lux on the level. These emergency lamps are connected to a specific uninterruptible power supply exclusively dedicated to this circuit. The emergency lighting panel (Q0) and the relative uninterruptible power supply are located in a box at the bottom of the cave.

Security lamps

1. *Glim Cube (iGuzzini)* (wall lamp with a 3-LED electronic transformer). Wall lighting device designed for the use of LED light sources composed of a screen and a support base. Polymethyl methacrylate ribbed screen, support base in pressure die-cast aluminium, catch plate in stainless steel and grains M5x10; stainless steel PG11 cable gland; power supply unit provided with a 3W - 350 mA electronic power supply. All screws are made of A2 stainless steel. The technical features of the appliances comply with the EN60598-1 regulations and specific requirements. IP66. IMQ-ENEC certification. Protection class II. 322 *Glim Cube* lamps were fitted, 305 of which in the cave and 17 on the exit pathway.

2. *Fluorescent lamps*. Luminous body provided with a base to be fitted on a low wall, 14W fluorescent lamp, *Warm White* light, equipped with anti-glare screen. 19 lamps were fitted in the artificial tunnel.

Lampenflora

The development of *Lampenflora* (algae, moss, cyanobacteria and other opportunistic plants) is induced by the lights in show caves. These photosynthetic species can seriously damage the underground ecosystems.

In order to ensure the appreciation of the cave and to minimize the ecological and aesthetic impact, the *Grotta Gigante* was mainly lit by MasterColor metal halide lamps, with a colour temperature of 3,000 K.

Furthermore, after thorough research and after checking market availability, it was deemed necessary to use auxiliary germicidal lamps, provided with an electronic starter, like the TUV Xtra 36W fluorescent tubes produced by *Philips*, which obtained the 2008 *Green certificate* (Photo 3), in order to inhibit the development of *Lampenflora* and to ensure an environmentally-friendly use of the cave.

23 double ceiling lights, like the AISI 316 2X36 W, and 5 single ceiling lights, like the AISI 316 1X36 W, were fitted. Both types are provided with an electronic ballast and made of tempered glass. These lamps, whose use aims at keeping the development of *Lampenflora* under control, turn on when all the other lights in the cave are turned off.

Digital amplification system (en 60849 certification)

A new audio amplification system was installed, in compliance with the IEC 60849 requirements, and divided into two racks, one inside the cave, provided with all the power amplifiers, and the other outside the cave, with the control station, its sources and a microphone for general announcements, connected to a ring optical fibre system, to ensure the functioning of the system in case of an interruption on the system cable.

There are three positions for guided tours, and thanks to a local keyboard it is possible to deliver a descriptive message in the desired language. It is also possible to use radio microphones inside the cave for conferences and other events.

The loudspeakers were chosen after a series of tests carried out inside the cave by means of acoustic instruments, and are produced by the well-known German company “LB LAUTSPRECHER”, which carried out a suitable customization for use in a difficult environment, such as a cave.

At the end of each line of loudspeakers an electronic card communicates the correct

functioning of the system to the control station. In the event of a failure, a LED flashes on the microphone station and an alarm beep warns the operator. Furthermore, in the event of a failure of one of the amplifiers, a back-up amplifier comes into operation, thereby ensuring the correct functioning of the system.

Radio communication system

As regards communication between the inside of the cave and the fixed listening position, located in the ticket office of the *Grotta Gigante*, a radio transmission network (*Motorola*), provided with an auxiliary relay, was chosen, in order to be able to communicate from anywhere inside the cave with the external operator or vice versa.

The *Motorola* radio system, characterised by DMR technology, consists of:

a. 1 *Motorola DM3000* relay station, located in a watertight steel cabinet and provided with a 20W heater, power supply system and antenna splitter;

b. 1 internal/external antenna system composed of a Uhf RF330NZ omnidirectional antenna and a Uhf RF611NZ directional antenna;

c. 1 *Motorola DM3600* base station to be installed at the ticket office counter and equipped with power supply, buffer battery, microphone and internal antenna;

d. 6 *Motorola DP3601* portable radios equipped with battery, antenna, belt clip and battery charger.

This radio system has been designed for communicating inside the cave and for emergency use. For standard conversations operators can talk to each other from one portable radio to another and with the base station, by simply pressing the PTT button on their portable radio or on the base station. All portable devices have an orange button on the upper part of the radio: in the event of an emergency, by pressing this button a fixed transmission cycle is activated and for 15 seconds the operator is able to voice-communicate his/her position and to explain the reason for the emergency to the other devices and to the base station. After 15 seconds the radio resets and the base station and the other portable radios

will be able to communicate with the operator who signalled the emergency. The portable devices are also provided with a *man down* function which automatically sends an emergency call when the portable radio is kept in a non-vertical position.

Scientific installation

The power-supplied scientific instruments (the University pendulums and the O.G.S. seismograph) are protected with special differential thermal-magnetic devices. Furthermore, 2 divisional metering devices for consumption meter reading were installed.

Temperature monitor

Inside the *Grotta Gigante* a temperature sensor was installed. The data relating to this sensor are displayed on the maxi screen, which is also used for meteorological data, located in the waiting room of the *Visitors reception centre*. The temperature sensor used in the cave consists of a Pt100 platinum thermal-resistance element with a response curve in compliance with DIN 43760 regulations, class 1/3. The transducer belongs to the category of intelligent sensors since it is equipped with an internal microprocessor which checks the correct functioning and also has data pre-processing and A/D electric signal conversion functions and so on. These features guarantee highly accurate and reliable data. The transducer complies with the European EMC standards, is protected against overvoltage and fully complies with the WMO (World Meteorological Organisation) requirements.

Consumption

As well as considerably improving the cave lighting and installing safe equipment, the electrical system's energy consumption was certainly reduced, by sizing the distribution cables of the various circuits and the protection devices with back-up function, whose section was increase. The main switchboard, located in a special technical room in the basement of the *Visitors centre*, is provided

with special equipment for the measurement of power parameters, in particular *voltage* and *current*, which can be checked at any time. The average absorption of electricity amounts to 45 A, which means that the resultant active power of the entire electrical system (*Cave* and *Visitors centre*) is almost 50 % lower than it was before the replacement of the system.

Making the existing handrail safe

The steep stairs and aerial pathways which extend throughout the *Grotta Gigante* are provided with handrails which protect visitors from dangerous falls. Most parapets had already been carried out in compliance with the safety measures in force (1 m minimum height and vertical elements at a minimum interaxial distance of 10 cm) and in non-deteriorating and non-polluting material in the cave environment (stainless steel).

36 metres of obsolete parapets were replaced with others of the same kind and material (stainless steel) as the recently installed ones and 6 metres of stainless steel handrail were also installed.



Fig. 3. Speleothems in *Grotta Gigante* (this photograph was taken thanks to the lighting of the TUV Xtra 36W fluorescent tubes). Photo: A. Fabbricatore