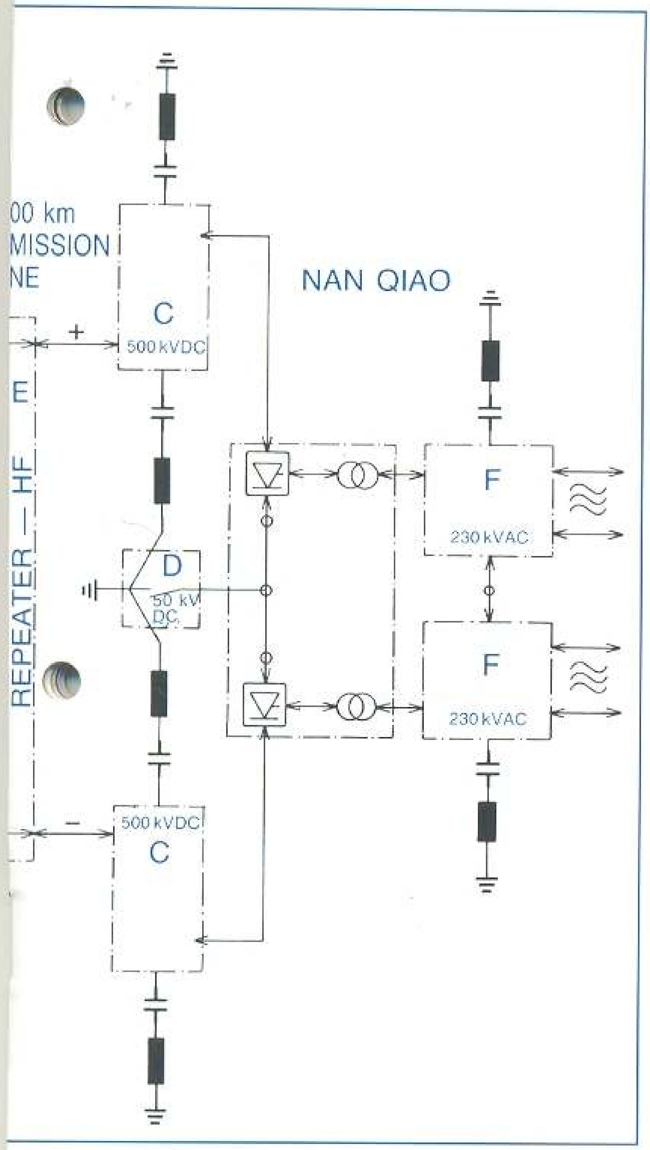

The substations

The prerequisite for HVDC transmission are substations transforming the AC produced at one endpoint to DC and retransform it to AC at the other endpoint. Fig. 9 shows the block diagram of the individual substations of the GESHA project.

The "point of departure" for the energy transmission to the East is the 525 kV AC outdoor substation in Gezhouba. This is where the AC enters the valve halls and is transformed to ± 500 kV DC. (The point of symmetry led out of the valve halls is insulated to 50 kV and connected to the earth electrode at a distance of approx. 30 km. At the adjacent 500 kV DC outdoor substation the DC is smoothed and switched onto the 1,000 km long overhead line. After some 500 km, the line passes a HF repeater station in order to compensate the HF losses and distortions resulting from the length of the transmission. At the endpoint in Nan Qiao, DC is retransformed to AC and fed into the distribution supply network of Shanghai by means of the 230 kV AC outdoor substations.

The following sections describe the connectors used for the individual substations without going into detail as far as standard parts are concerned.

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The supplier of the connectors has to take full responsibility — and this applies not only to the technical quality of his products: the connectors also have to protect other components of the system.

A wind speed of 130 km/h, an ice load of 2 cm, an earthquake and a short-circuit: whatever force of nature is unleashed, connectors and fittings have to remain unchanged.

The substation connectors

All connectors and fittings to be used in the substations had to meet the following requirements:

- **Corona**

When exceeding the respective nominal voltages by 20%, discharges must neither be seen, nor heard nor measured.

- **Shielding**

The connectors must be designed in a way that a reliable shielding of the post insulator heads and the appliance terminals is safeguarded.

- **Energy transmission**

Constant currents of up to 2,500 ampere must be transmitted with the least possible loss.

- **Short-circuit strength**

The connectors must stand the mechanical and electrical stresses resulting from a short-circuit current up to 50 kA1s.

- **Earthquake resistance**

As seismic activities might occur in the region concerned, all connectors and fittings must be calculated, produced and tested correspondingly.

- **Stresses resulting from wind**

The mechanical dimensions of the voluminous shieldings as well as the measures for dampening the wind-induced oscillations at the outdoor stations were based on the wind speed of up to 35 ms^{-1} reported by the client.

- **Ice load**

The ice layer on the conductors which had to be expected for Gezhouba was specified as 20 mm.

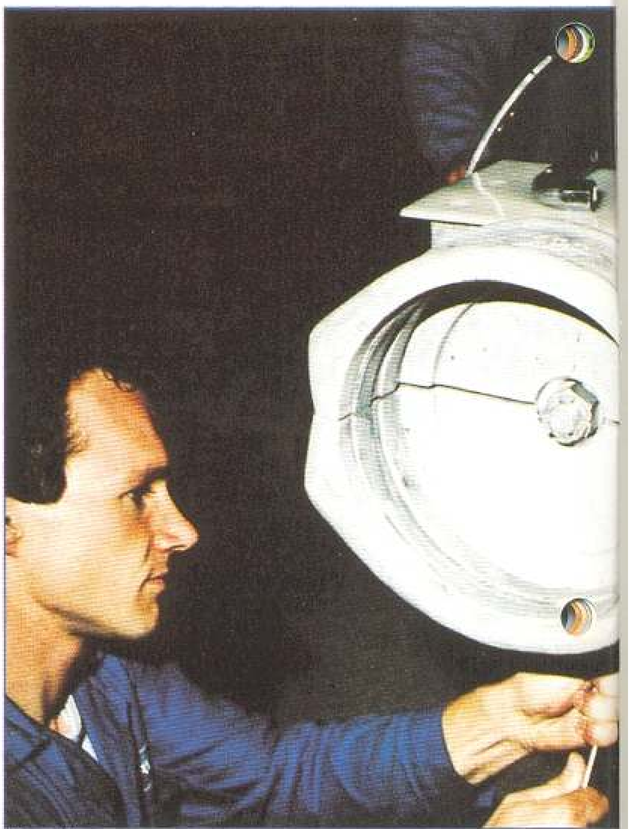


Fig. 10

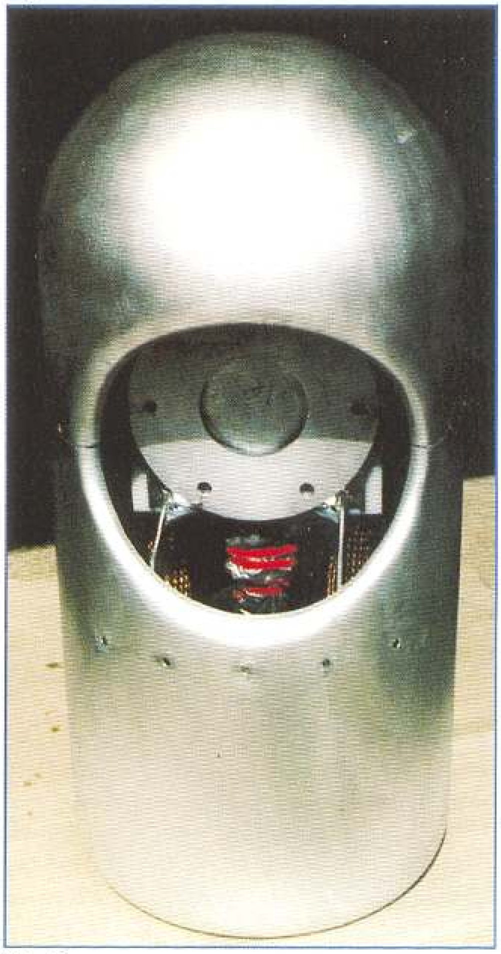


Fig. 11

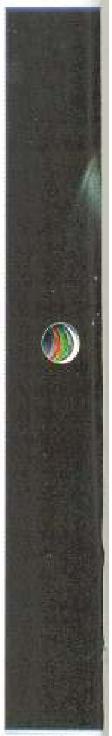
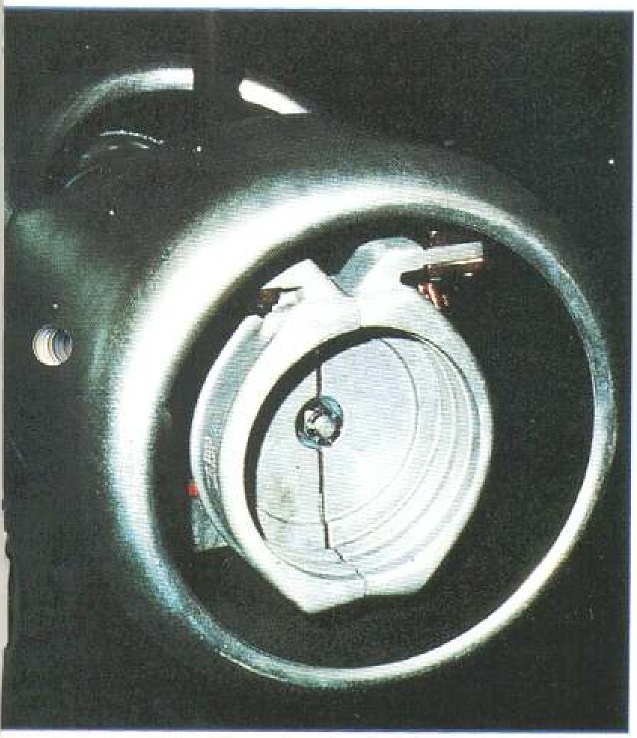


Fig. 12

Fig. 10—1
dimensions



: This example of a tube connector gives a good impression of the
of the valve halls.

Terms of delivery

When carrying out a large-scale project such as the GESHA project, each supplier has to be highly flexible, open-minded, cooperative and technically qualified in order to meet the individual requirements resulting from the specific conditions and standards. Thus, as a matter of fact, standard fittings and connectors cannot be used either. They have to be "purpose-designed and -built". Calculations, research, practical and security tests are necessary until the new product, a highly developed and extremely important "module", can guarantee interference-free service of the entire system.

Moreover the project management expects every supplier to contribute his share to the intensive research and engineering in general. As a consequence, the supplier of the connectors also set up various mounting arrangements and documentations and determined the actual shape of the connectors and the number of connectors necessary for the individual divisions of the contract, using the overall plans and appliance terminal diagrams.

The supplier is the only responsible for all these activities.

When LORÜNSER was awarded the order for the development of the connectors for the GESHA project, the 100 staff members of this traditional firm belonging to the MOSDORFER-KNILL group, situated in the Province of Vorarlberg/Austria, were looking forward to enormous challenges, the development of new products, new designs, product presentations and adaptions, exchange of information and experience and special meetings. Moreover they had to stick to the tight schedule. Only 6 months lie between the awarding of the order and the delivery of the connectors. Three factors, however, made it possible to fulfill this task on time: the technical know-how and the experience of many years of LORÜNSER, the examplary cooperation with the ABB/Siemens consortium and the personal commitment of every single staff member.

The Far East embodies the notions of industry, commitment and precise execution of any task. Therefore, every European firm which wants to live up to the requirements of this market and win a good reputation has to integrate the same qualities in its own business.

Apart from technical know-how, the calculation and development of a connector also requires a lot of time. Of course, they should last forever...

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Section A:

525 KV AC outdoor substation Gezhouba

The substation Gezhouba feeds the AC produced by the generators into the valves which then transform it to DC. The substation is designed for a nominal current of 2,500 ampere per busbar.

The switchboard sections are designed for 1,250 ampere, the switching is done by the bundled conductors and tubes. Fig. 13 shows one section of the switchyard with busbars (A), terminal (B), appliance terminals (C), top strings (D).

The utmost principle of connector design is avoiding any sort of edges and burrs. Any of these defects in casting might cause an electrical discharge at the clamp.

• The 525 KV AC switchyard and its connectors

The fittings for the 525 kV AC switchyard Gezhouba form a major part of the order. The 250/150 kV AC standard connector was used for the filter of this substation. The 525 kV AC connectors, however, required a special design.

Due to the large number of different appliances and connections, special types of connectors were used for the specific situations. Fig. 15 shows a typical conductor connector for quadruple bundles: The conductors are fit into the exactly turned-out grooves of the lower part of the connector by means of caps screwed onto the connector.

Then, the connector is mounted onto the appliance terminal, either with a special cap (in case of a pin joint) or with packing screws (in case of a flat terminal). The lower part of the connector serves as a transmitter. As the risk of corona is very high in this special voltage range, major attention has been paid to a round, crowned shape of the connector.

Fig. 17 and 18 show another typical connector for this substation, the tube connector. Apart from energy transmission and fastening, this connector also facilitates the longitudinal enlargement of the tube conductor as a result of the heating of the conductor. For this purpose, the conductor is put in an especially flexible expansion bus support (fig. 17); an external stud constituted by flexible SAl-cables facilitates current passage with as little resistance as possible. This type of tube connector is used for both the appliance terminals and support connectors for insulators, e.g. busbar connections.

Holding strength, stress resistance and high flexibility are the most important characteristics of these tube connectors.

Due to the risk of corona, the tube connectors have to be round and edgeless as well. At highly dangerous positions, e.g. the endpoint of the busbar or the insulator heads, additional shielding is required (fig. 16).

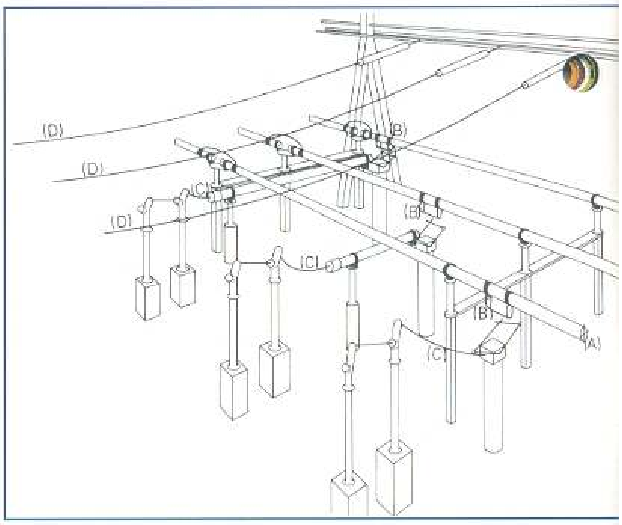


Fig. 13: Scheme of a typical section of a 525 kVAC switchyar appliances and top strings. Every terminal and junction or nodal poi tors requires special connectors.

Fig. 15: Straight flat terminal for quadruple bundles.

Fig. 17: Flexible expansion bus support: this connector does not only serve as a safe mechanical support but is also very flexible (dilatation, oscillations).

Technical data on the 525 kVAC switchyard connectors

Operational voltage: 525 kVAC/50 Hz
Constant current: — 1250 A (switchboard sections)
— 2500 A (busbar)
Short-circuit current: 50 kA1s
Conductors: — 250 mm tube (busbar)
— 160 mm tube (appliance terminals)
— 4 x 32.6 mm Al strings / 80 x 80 mm apart (appliance terminals)
— 4 x 32.6 mm Al strings / 200 x 200 mm apart (top strings)
Application: — connections and terminals of the tube busbar
— appliance connections and terminals
— top strings

...with busbars, ...of the conduc-

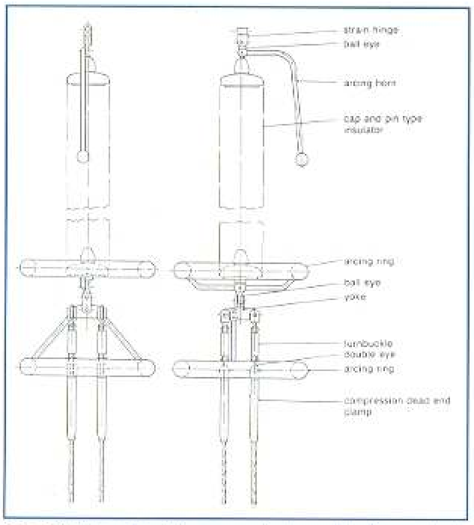


Fig. 14: The top strings are fastened to the portals by means of tension strings and compression clamps. The in-built tension jacks facilitate exact definition of the sag.

Fig. 16: Tube support for the endpoint: the vertical ring shields the end of the busbar (high risk of corona discharge), the horizontal ring protects the shielding of the insulator head.

Fig. 18: Stud for a current passage from one end to the other end of the tube without any losses.

In order to transmit the current from the busbars to the pantograph switch in the individual sections, special connectors with annular suspension points are applied; they serve as a flexible suspension of the pantograph switch cooperating contact (fig. 19).

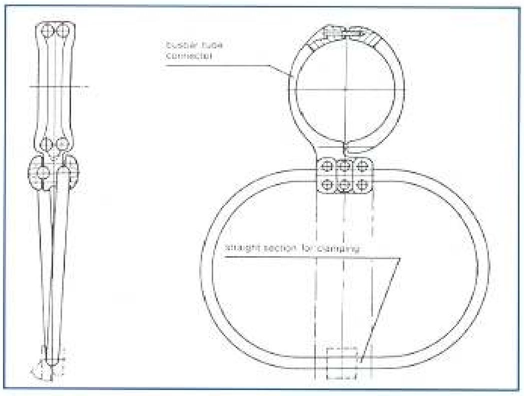


Fig. 19: Four-wire connectors with annular suspension points are mounted in pairs onto the busbar tube and connected with a pantograph switch in the lower part.

Additional 525 kVAC connectors

Apart from appliance terminal connectors and busbar connectors, the order also contained various types of spacers for bundled conductors, suspension clamps and parallel groove clamps.

The 525 kVAC shieldings

Thanks to the compact, round design of the connectors, additional protection fittings were only necessary for the "neuralgic points", such as the endpoints and the turns. The major part of the connectors (LORÜNSER connector series "525 kV") used in the substation Gezhouba could be applied without protection fittings.

The 525 kVAC tension strings

The tension strings chosen for top stringing were applied with or without tension jacks. Compression clamps combined with a MOSDORFER 1000 kN mounting press are used for the clamping of these strings. Test results proved that corona rings were not necessary for the fitting of the tension strings. Fig. 14 shows a 525 kVAC tension string for quadruple bundle with tension jack design (in this case with glass cap type insulators).

Section B:

The valve halls

The valve halls are characterised by high voltages, measures for earthquake resistance and limited space.

In the valve halls of Gezhouba and Nan Qiao, 525 and 230 kV AC respectively are transformed to ± 500 kV DC by means of banks of transformers and valve towers. Three voltage ranges are coupled in the connections as well as in the AC-DC and DC-AC converters:

- ± 500 kVDC
- 525 kVAC/50 Hz and 230 kVAC/50 Hz respectively
- 50 kVDC Ground Electrode

Fig. 20 and 21 show a valve hall. The valve towers, which, due to their own weight of 30 tons, have to be suspended, immediately catch one's eye.

The valves with an own weight of 30 tons are suspended in order to compensate the oscillations resulting from an earthquake.

Fig. 20: Interior of the valve hall (model):
The lower transformer feed-throughs form star points and are connected by 160 mm Al tubes. Special expansion connectors facilitate the connection and the storage of the tubes and allow for the expansion of the tubes. Due to the boundary field strength resulting from the operational alternating voltage, the connectors have to be protected by a toroid which is made of aluminium because of weight considerations.
The upper feed-throughs lead the phase voltage and are connected by 2x920 mm² Al bundled conductors. The appliance terminals used must be shielded as well.

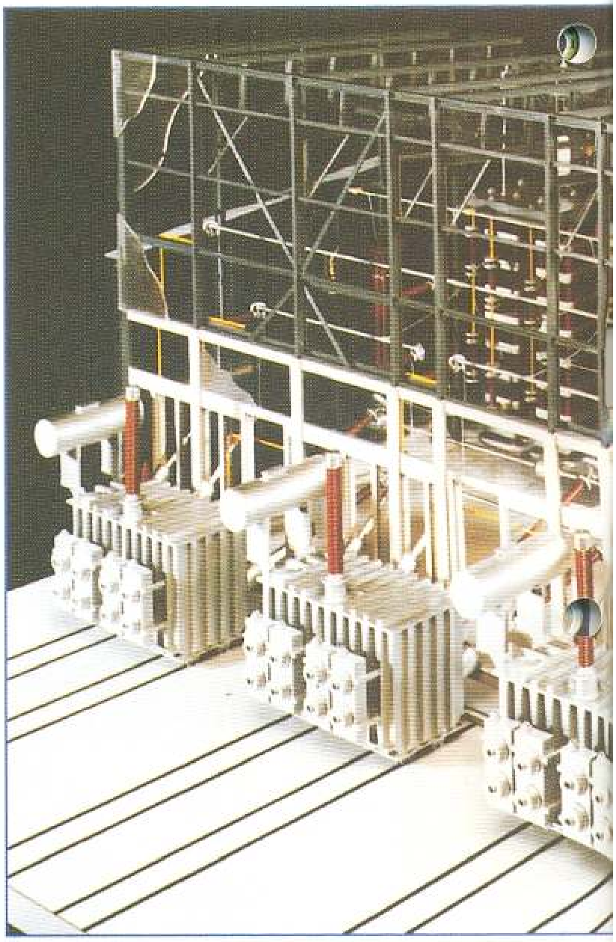


Fig. 21: Total view of the valve hall (model): In the front, there are t
transformers is led into the hall by means of feed-throughs.

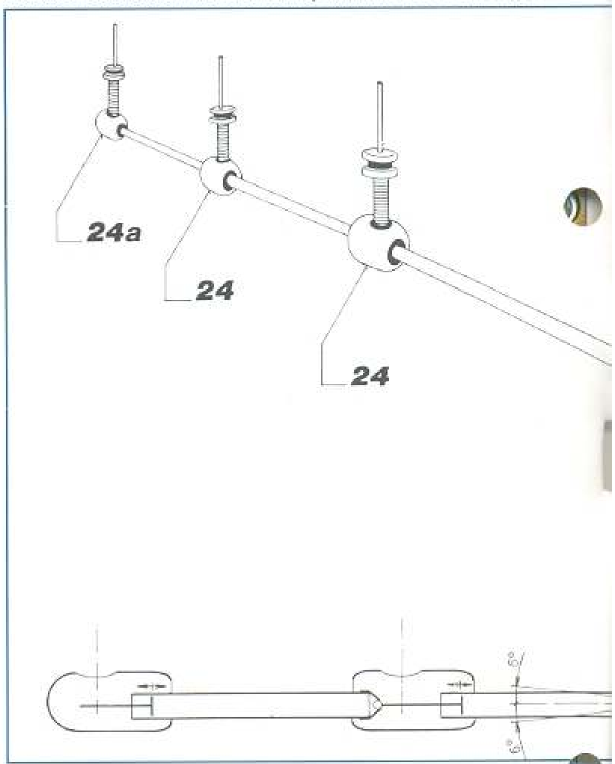
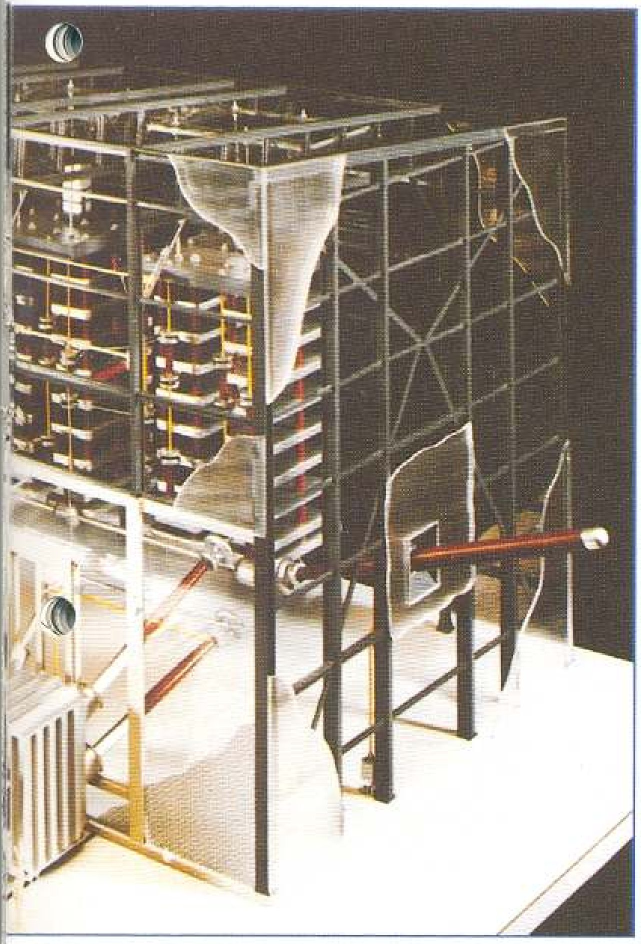
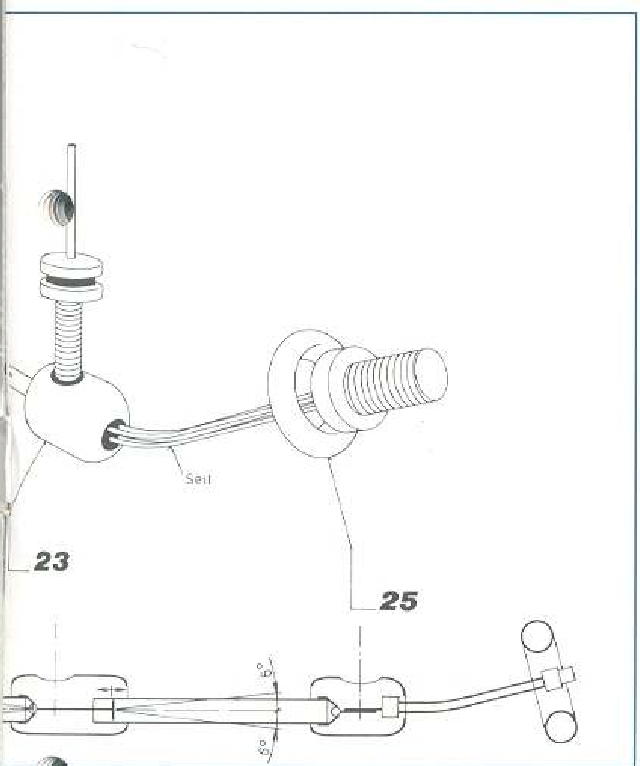


Fig. 22: Diagram of the suspension and the terminals of the 50 k
detailed figures.)



transformer groups, which feed the valve hall. The voltage of the



C busbars in the valve halls. (The numbers refer to the corresponding

In order to keep the costs for building as low as possible, a very compact design was chosen for the valve halls. As a consequence, the voltage-carrying bars lie very closely next to each other, which meant special requirements for the design of the connectors with regard to corona protection.

• The 500 kVDC switching

The tube-shaped 500 kVDC busbar is fastened at the shunt conductor flange facing of the valve towers. As the valve towers are assumed to produce a conical thrust in case of an earthquake, the tube connected with the shunt conductors is divided into various parts (fig. 22). The LORÜNSER special connectors developed for this specific case serve for fastening, shielding and transmission. Due to the expected thrust, these connectors must be particularly flexible (cf. "500 kVDC tube connectors").

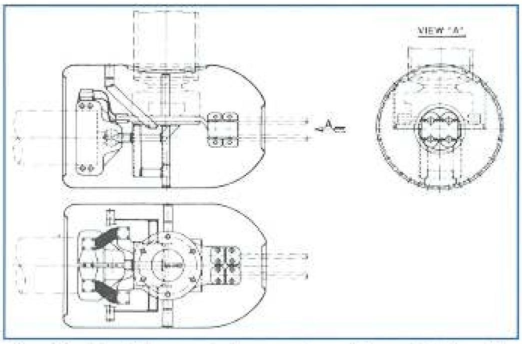


Fig. 23: Flexible special connectors (fix point) for the connection of shunt conductor and tube: The tube is connected with the shunt plate and the bundled conductors by means of studs made of highly flexible copper bonds (cf. fig. 10 — 12).

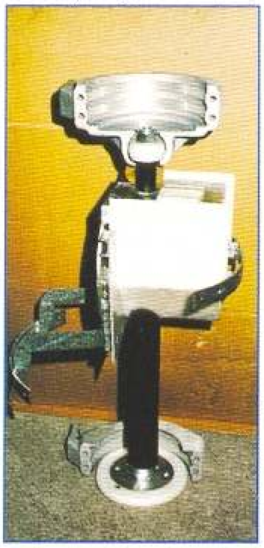


Fig. 24 **Fig. 24a**

Fig. 24: Supporting part of a special connector for the connection of two tube ends and its fastening to the shunt conductor flange.
Fig. 24a: Similar special connector for being mounted at the endpoint.

A shielded supply terminal was used for the indoor terminal of the 500 kVDC feed-through. The supply terminal also takes up the cooperative contact of the system earth (cf. "500 kVDC conductor connectors").

• The 500 kVDC tube connectors

As already mentioned, the valve hall connectors required a special design because of the limited space available. Fig. 22 shows one of those typical mounting situations, which made the development of a special connector necessary. All these tube connectors have the following features:

- Suspension at the shunt conductor flange (the base is conducting)
- Insulated supporting framework
- Firm bedding by means of a plastic joint
- Gliding bedding as insulated leader inside the tube
- Highly flexible Cu-wiring facilitating excellent transmission from base to conductor and from conductor to conductor
- Al-sheet protection tube fastened to the supporting framework by screws, which required particularly careful production

These design principles, which have been tested on our premises as well as at ABB / Baden, are the same for all connectors. The terminals, however, vary, which leads to minor variations in shielding and the supporting framework.

• The 500 kVDC conductor connectors

Bundled conductor terminal connectors with special shielding design were used for the feed-through terminal from the pin to the bundled conductors. Fig. 25 shows one of these connectors, which also provides a connection facility for the mounting of an earth contact included in the shielding.

• The 525 kVAC switching

The 525 kVAC tube connectors facilitating the connection of the AC transformer feed-throughs correspond to the design of the 525 kVAC switchyard described above. The same applies to the conductor connectors facilitating the AC connection of the feed-through and the valve. Fig. 27 shows an expansion connector type which serves as tube conductor terminal at the feed-through pin.
Apart from expansion tube connectors, also

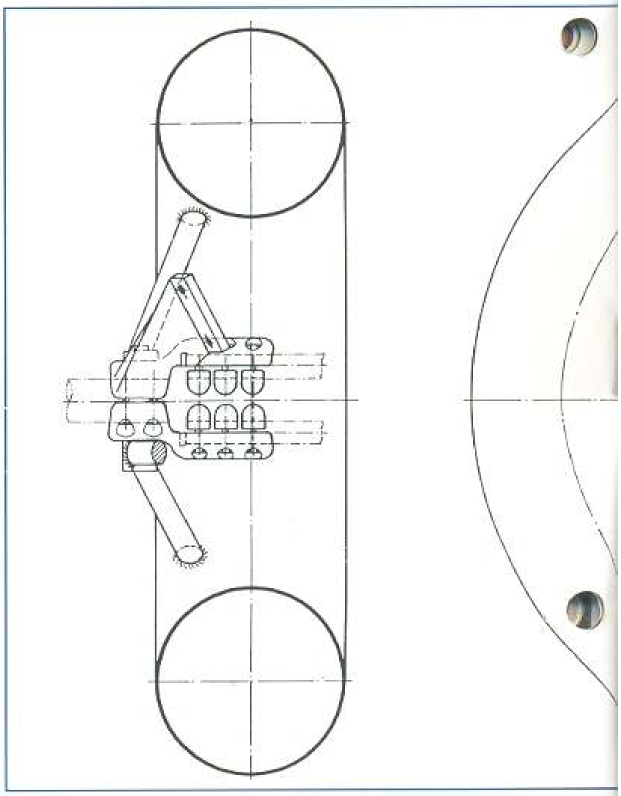


Fig. 25: Connector for bundled conductors with take-up plate for th

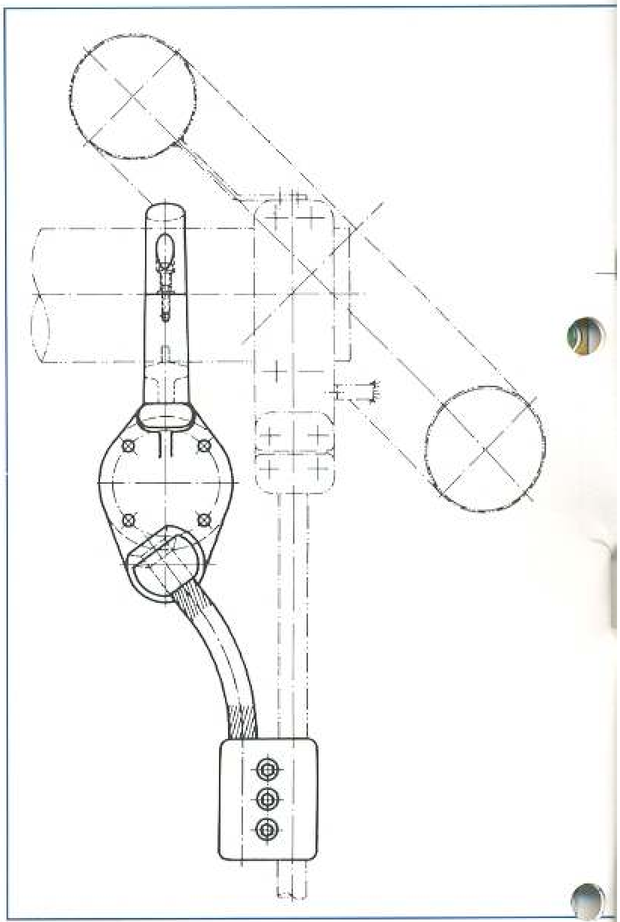


Fig. 26: Angular tube conductor support with earth contact at the