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FINAL REPORT

HVPNL
SYSTEM EFFICIENCY IMPROVEMENT TRAINING PROJECT

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(i) Preliminary Report on Task Order N° 20, August 1998

(ii) Substation Preventive Maintenance Manual, August 1998

(iii) System Efficiency Improvement Training Project, Scope of Work, Implementation Approach, and Schedule of Training Activities, August 1998

2.0 INTRODUCTION

The United States Agency for International Development (USAID) approved for HVPNL, a System Efficiency Improvement Training Project International Resources Group (IRG) has now provided this training to the selected participants (about 85 engineers) from HVPNL HVPNL assigned Mr K D Dogra, as a Project Co-ordinator to work with the IRG Training Team

3.0 TRAINING PROGRAM

The training program was structured to provide the trainees with the necessary tools and knowledge to design, operate and maintain a more reliable, safer, and more efficient electrical system

HVPNL had three training centers that were used as venues for the classroom training Three groups of approximately 10 trainees each were selected for training from each of the three centers Selected switchyards were used to provide on-the-job training for each of the 9 groups See Appendix VII Appendix VI was used as an inspection check list for the walkdowns done at the switchyards

4.0 5 DAY SEMINAR

Each group of trainees had to attend a 5-day seminar consisting of four 8 hour days of lectures, one 4 hour night of thermo-vision scanning, and one 8 hour walk-down of a switchyard

For details of the seminar and complete coverage of the classroom lectures see Appendices I II and III

5.0 WALK DOWNS & THERMO-VISION SCANS

Appendix IV contains the results of the walkdowns at the switchyards and the night scanning at these same switchyards Note that scanning could not be done at the first three switchyards due to the unavailability of a thermo-vision scanner at the time A

scanner was rented for group 1A however to give them a feel for the "hot spots" identified at Pinjore substation No scanner images however were made available from the renter

6.0 OBSERVATIONS AND RECOMMENDATIONS

6.1 SWITCHYARDS

6 1 1 POWER TRANSFORMERS

6 1 1 1 Foundations

Observations

In nearly all existing installations (except at Hissar 220 kV swyd), the transformer foundation consisted of two concrete support plinths with steel reinforcement with I sections bridging the two plinths This design does not provide for

(a) Containment of the oil during a tank rupture
Or, (b) Quenching of surface flames on burning oil that has spilled out

Recommendations

Modern practice requires transformers to be installed on a concrete 'pan', with the bottom sloped, to a drain point where spilled oil could be then pumped to an off-site location The pan or shallow open tank should be designed to catch all the spilled oil and 60% volume of the tank should be equal to the total volume of oil in the transformer

The balance 40% volume of the open tank should be filled with crushed granite rock This helps to break up any surface flames on the oil and quenches the fire as the oil, seeps below the crushed rock

6 1 1 2 Overvoltage Protection

Observations

On all transformers, the overhead bus terminating at transformers should have surge arresters on both the HV and LV sides of the transformer In some instances these arresters have not been installed (eg Pinjore switchyard)

Recommendations

All power transformers connected to overhead buses or exposed bus should have surge arresters installed on both the HV and LV sides of the transformer The arresters must be co-ordinated with the BIL of the transformer windings, must be located as close to the transformer bushings as possible, and must be station class, and have a

metallic ground connection (via the ground grid is O K) to the transformer grounded neutrals, and the tank

6 1 1 3 Protective Relaying

Observations

In some cases (eg Babyal switchyard) the transformer high side breaker is non functional electrically and also the blue phase has been jumpered out This means that when the transformer differential relay operates, and calls on the high side breaker to open, the breaker being non-functional cannot isolate the faulty transformer This could eventually result in a fire and the total destruction of this expensive transformer

Recommendations

In each case where a breaker is jumpered out or is non-functional the transformer protective relay zone must be adjusted to overlap healthy breakers and the tripping times should be comparable to differential relaying, and isolation of the faulty transformers should be complete from both HV and LV sides

6 1 1 4 Fire Protection

Observations

When transformers are mounted side by side, sometimes the minimum distance achieved between transformers is insufficient to prevent the spread of the fire from the faulty transformer to a healthy transformer

Also transformers located close to walls of the control building have insufficient distance to the walls to prevent the fire spreading to the building

The only fire protection provided on the larger power transformers is a portable CO_2 cylinder type extinguisher and about 5 small buckets filled with fine loose sand

Recommendations

Transformers located side by side should be seperated by a fire wall

Transformers close to building walls should have the walls designed for a 2 hour fire rating

A better, and automatic fire extinguishing system should be provided, particularly on the large, more expensive and more important transformers This should consist of a piped 'mulsifyr' system utilizing a ring of smoke and heat detectors located at strategic points around the transformer

In the absence of automatic fire protection equipment due to say, economic reasons, it is imperative that fast protective relaying with adequate reliable backup relaying be provided

6 1 1 5 Maintenance

Observations

Oil levels may be low, oil leaks are evident at cooling radiator gaskets and sampling valves, and at tank cover gaskets

Silica gel breathers have pink crystals

In some instances, oil cups on the breathers are missing

Temperature indicators in some cases are not operating correctly (WTI reads lower than OTI) (e g Madhanpur switchyard)

One incident was reported by a trainee of IR levels on a transformer reading lower than the manufacturer's recommendations

Thermo-vision scans may show unusual conditions such as local heating, blocked radiators, restricted oil flows, insufficient or inefficient cooling, low oil levels

Oil testing of sampling may show low dielectric strength

Fan controls in the transformer control cabinets have been left on the "manual" position This could overheat a fully loaded transformer since it is deprived of it's cooling

Recommendations

- The O&M manuals for each and every transformer must be made available at each switchyard Periodic maintenance as recommended by the manufacturer must be carried out religiously, rigorously, and promptly All maintenance procedures should be followed throughout the life of the transformer and all maintenance logs must be maintained for reference

- Transformer fan controls should be left in the 'auto' position to enable the transformer to get adequate cooling during heavy loading conditions

6 1.2 LIGHTNING ARRESTERS

6 1 2 1 Inclusion in circuits

Observations

Lightning arresters are missing on

(i) On some transformers where overhead lines or buses terminate on transformer bushings

(ii) On some cable to overhead line interfaces

And (iii) At the open circuited ends of some HV overhead lines

Recommendations

The appropriate lightning arrester (i e station or distribution class) must be inserted at the interface of all equipment of a particular impedance when connected to equipment of a different impedance

e g at the interface of transformer/OH line,
at the interface of cable/OH line,
at the interface of Open Isolator/OH line

The arresters must be placed as close as possible to the equipment it is protecting This has not been the case at Babyal, where the 66 kV arresters could have been placed closer to the transformer, and in place of the bus support insulators

6 1 2 2 Grounding

Observations

HV lightning arresters are 'grounded' via the leakage current ammeter/surge counter black box The ground connection thru' the black box cannot be seen and may be 'open' which means there is no overvoltage protection

Also in nearly all switchyards, mild steel bars are used for grounding This bar may be corroded either above or below ground level which would again defeat the required grounding of the lightning arrester

Recommendations

Verify the continuity of the ground bar thru' the black box Verify the continuity of the ground bar all the way to and including the ground grid

6 1 2 3 Monitoring

Observations

- In possibly 90% of all switchyards the HV lightning arrester monitoring circuits are defective They are corroded, unreadable, and/or non operational As such the leakage current flowing thru the arrester is not known Only a limited leakage

current is permissible thru' the arrester and when the limit has been exceeded (ammeter needle goes from green scale to red scale) the arrester MOV discs are exhausted and the arrester has to be replaced

Recommendations

A calibrated, functioning leakage current monitor must be connected in the arrester ground circuit in place of the defective monitor and the actual leakage current present must be determined If leakage current exceeds the limit then the arrester must be determined If leakage current exceeds the limit, then the arrester must be replaced, as the protective capacity of the arrester has been exhausted

6 1 2 4 Maintenance

Observations

- No maintenance logs are kept on lightning arresters As such a false sense of security is achieved, since equipment provided with an "arrester" may in fact have no overvoltage protection

Recommendations

Maintain logs of arrester leakage currents, ground connection resistances, number of surge counter operations, and calibraion of leakage current ammeters

6 1 2 5 Connections

Observations

In one switchyard (eg Beer swyd) 132 kV side arresters at 132 kV - 33 kV transformer) the arresters had been incorrectly connected The leakage current monitor had been shorted out of the ground circuit It was also questionable whether the arrester base was in fact grounded!

Recommendations

Each arrester must be correctly installed with the monitor included in the ground circuit and the arrester base grounded through the monitor

6 1 3 CIRCUIT BREAKERS

6 1 3 1 Manual Control

Observations

At Beer and Hisar 220 kV switchyards there were 132 kV SF6 breakers that had electrical control both locally at the breaker and remotely in the control building However there was no manual control at the breaker In the event of an emergency, if

the electrical power is not available at the breaker (which is quite a likely occurrence) the breaker cannot be tripped manually at the breaker This is a dangerous situation

Recommendations

HVPNL should specify on all breakers, that manual, mechanical controls should be provided at the breaker

6 1 3 2 Inclusion in Incoming Circuits

Observations

In some switchyards (e g Beer and Nilokheri) the main incoming HV line connects directly onto the HV bus in the switchyard without having an isolating incoming circuit breaker

There are some disadvantages to this Firstly, to cut off power to the switchyard the remote switchyard breaker has to be opened (by manual communication)

Secondly, the HV bus differential relay has to isolate the bus in the event of a bus fault How is this to be accomplished without a local breaker? If there are no HV bus differential relays how does the distance relaying on the incoming line at the remote station cover the HV bus zone? There are no satisfactory answers to these questions

Recommendations

The above questions indicate many disadvantages to not having an incoming HV circuit breaker The relaying and operation of the system has to be looked at closely and must be designed to give safe and efficient operation of the system

6 1 3 3 Shorting out of Phases

Observations

At more than one switchyard (e g Babyal) circuit breaker, phases have been shorted out At Babyal, the incoming circuit breaker is a 3, individual pole, ganged breaker The pole of the blue phase was non-functional and as such had been jumpered across Also, it was determined later that the control switch had been disconnected, the reason being that the electrical charging motor was defective and the breaker (red and yellow phases) had no electrical circuits

Leaving a breaker in this condition on a live circuit is a safety hazard, and provides a false sense of security Losses are also increased due to the connectors and contact resistances (I^2R losses), unnecessarily being left in the circuit Protective relaying is jeopardized because of a non-functioning breaker and the fact that the blue phase circuit cannot be opened, and the protective zones may not have been revised

Recommendations

The relaying zones must be re-arranged to give overlapping protection and tripping circuits must be re-connected to trip functional breakers that will isolate any fault, completely Some flexibility will definitely be lost due to the reconnections and therefore the faulty breaker must be removed and replaced as soon as possible A log should be kept at each switchyard to order needed replacement equipment and this should be intimated to HVPNL management on an 'as needed' basis

Leaving the faulty breaker in place with no revision to the protective system could result in a power transformer fault developing into a major transformer fire and ultimately destroying the transformer with danger to human lives (See Reference Reports for the concern of HVPNL Chairman in regard to the recent 5 large power transformer fires that occurred in 1998)

6 1 3 4 Operation Counters

Observations

Very little, or no, attention is being paid to circuit breaker operation counters In some cases the counters have not been maintained and operating personnel don't even know where to locate these counters

Recommendations

The counters are located in the outdoor breaker control cabinets They should be periodically checked for correct operation, and their gearings should be lightly oiled Manufacturers O&M manuals must be made available for operating staff at the switchyard and the switchyard SSE must prepare a maintenance procedure for each breaker based on the O&M manual requirements These procedures should be followed and logs kept of the maintenance performed on each and every circuit breaker The maintenance intervals are tied very closely to the digits of the operation counters, just like mileage intervals in an automobile

6 1 3 5 Maintenance

Observations

- There are many items which need to be checked for proper maintenance of the circuit breakers Some of these are

  - Operation Counters
  - Pressures, where applicable
  - Oil levels, where applicable
  - Vaccuum, where applicable
  - Contact resistance

- Overheating due to high contact resistance
- Other items indicated in O&M manuals

Recommendations

The manufacturer of the equipment is the best source for determining how the breaker is to be maintained Therefore the O&M manuals must be available at the switchyard for the SSE in-charge to be able to formulate a maintenance procedure Periodic thermo-vision scans of the breaker will help detect overheating or hot spots due to high contact resistance Functioning operation counters are required for determining routine maintenance intervals Correctly functioning gages help determine the maintenance of required levels, pressures, and vacuums

6 1 4 OVERHEAD SHIELD WIRES

6 1 4 1 Switchyards

Observations

All switchyards have overhead shield wires but over time, some masts have been removed, some shield wires have been removed, and also shield wires have been re-routed The net result is that in nearly every switchyard there is not 100 per cent coverage of the bus and equipment by the shield wires when a 30 degree coverage angle with the vertical is considered There are many "open" unprotected areas within the switchyards

Recommendations

Each switchyard must be looked at from a 'coverage' aspect and additional overhead shield wires should be installed to achieve the coverage of all switchyard equipment within the '30 degree cone'

The shield wire is regular GS wire, and in most cases the masts on the gantry towers are already in place, so the achievement of 100 per cent shielding is not an expensive cost item It is however very good and cheap insurance for protection of the switchyard equipment from direct lightning strokes

6 1 5 GROUNDING

6 1 5 1 Use of mild steel ground bars

Observations

For economic reasons and to deter pilferage, mild steel is used as the ground bus material, in lieu of copper As long as the correct cross sectional area, resistivity, etc was considered in the grounding calculations there is no harm in this However it must be borne in mind that mild steel corrodes easily and much faster than copper As such the effectiveness of the ground connections, ground leads, and ground grid must be checked frequently and periodically to ensure that 'corrosion' has not open circuited any ground connections

Recommendations

Frequently check the continuity of all external grounding leads Also, frequently check the ground grid resistance from individual isolated ground leads at various equipment locations The measured ground grid resistance in every case should be the same, since every lead is connected to the same ground grid If the readings at different locations in the switchyard differ, then this implies an isolation or "break" in the ground grid caused by corrosion of the mild steel This should be verified and the ground grid then needs to be corrected

6 1 5 2 Crushed Rock

Observations

All switchyards were designed with the "crushed rock concept" used in the grounding calculations Over time, this crushed rock has sunk below the soil, or weeds and grasses have grown through it's interstices Any of the above would destroy the high resistance properties required of the crushed rock layer, and thus defeat the purpose of the crushed rock surface

Recommendations

The crushed rock surface layer must be maintained throughout the life of the switchyard As such, all crushed rock surfaces must be free of weeds, and grasses, and when crushed rock surfaces are sparse, fresh crushed rock layer must be created by adding fresh crushed rocks to the depth required

6 1 5 3 Ground Grid

Observations

As indicated above, the use of mild steel bars for the switchyard ground grid requires more surveillance to verify that the ground grid below the surface is intact and not deteriorating, or deteriorated

Recommendations

Ground grid resistance must be measured from differing locations in the switchyard to verify that the grid has the same, identical resistance from wherever it is measured Also the resistance value should be recorded

Periodic Logs should be kept of the measuring locations and measured value, so that the quality of the ground grid is monitored and verified, and the grid is maintained

6 1 5 4 Maintenance

Observations

Deterioration of grounding and ground resistances below the designed values throughout the entire life of the switchyard cannot be allowed This includes or involves checking

- Ground connections of
  - all equipment casings
  - O/H shield wires
  - Power transformer neutrals
  - Lightning Arresters
  - Marshalling kiosks & cabinet enclosures
  - Structures
  - Cable armoring, sheaths
- Ground Grid, physical
- Crushed Rock Layer
- Ground grid resistance
- Weed control
- Periodic logs

Recommendations

All the above grounding parameters must be maintained, monitored, and controlled over the entire lifetime of the switchyard Anything less would cause an unsafe operating scenario with subsequent loss of human life

6 1 6 MV CABLES

6 1 6 1 Potheads and Stress Cones

Observations

3 Ph connection of 3 bare conductors to (1) 3/C cable is accomplished by a 3-ph Pothead with the stress cones on each phase as a part of the manufactured 3 ph pothead As such the phase-phase spacing at the top of the stress cones is predetermined and maintained fixed by the pothead manufacturer

When however, 3 ph connection of 3 bare conductors to (3) - 1/C cables is to be accomplished, 3 individual stress cones are used As such the ph-ph spacing at the top of the stress cones is not fixed, but must be maintained to be greater than but not less than the minimum ph-ph separation required for that voltage class This spacing must be ensured by the HVPNL staff during the installation of the cable to overhead jumper connections At Babyal, the 11 KV transformer bushings were connected by overhead jumpers to (3) - 1/C cables via individual stress cones The separation of the stress cones at the top ends was not controlled and the yellow and blue phase cones were very close together

Recommendations

Whenever single phase stress cones are used - always maintain the minimum ph-ph spacing for the voltage class of the cable, at the top of the stress cones (which are at line potential) by means of wooden spacer blocks located at the bottom of the stress cones (which are at ground potential)

6 1 6 2 Installation

Observations

In nearly all switchyards, the 11 kV side of the power transformers are connected by MV cables to the indoor metal-clad 11 kV switchgear The MV cables used are armored PILC in the older installations and XLPE in the newer installations In almost every case however, the cables which are meant for direct burial type installation are just laid exposed on the ground of the switchyard They are an obstacle hazard to vehicular traffic and human traffic and are subject to mechanical damage It shows also very poor housekeeping qualities

Recommendations

All MV cables from switchyard to indoor switchgear must be direct buried, if that is what they were designed for Snaking the cables haphazzardly along the ground surface is totally unacceptable and shows poor work practices, apart from the fact that it exposes them to mechanical damage, which could result in unsafe situations

6 1 6 3 Sheaths or armoring

Observations

The lead sheath of a PILC Cable or shield of a MV Power Cable (solid dielectric type) must be grounded at one point only Armoring of cables however, not meant for stress control are inherently grounded along their entire length

Recommendations

Verify in all cases that the stress control shield or sheaths of MV cables are only grounded at one end

6 1 6 4 Overvoltage protection, reflected waves

Observations

Where there is a discontinuity in impedance values (such as at an overhead line to cable interface) high reflected waves or surges could result These could damage the insulation of the cable if the magnitude of these waves was higher than the insulation level of the cable In some instances surge arresters have not been installed at this interface

Recommendations

Install surge arresters at all cable to overhead line interfaces An exception to this requirement is if the overhead line consists of only short jumper connections (such as from a transformer bushing to cable connection at the transformer tank) then the surge arresters may be omitted since the chance of direct surges on these short exposed jumpers is relatively small

6 1 7 CONTROL CABLES (600 V CLASS)

6 1 7 1 Ultra-Violet Deterioration

Observations

Control cables from circuit breakers current transformers, voltage transformers, isolators etc running from the control cabinets in the switchyard into the concrete cable trenches, in most instances run exposed These cables have PVC insulation, and not been run in conduit, are exposed to the sunlight PVC deteriorates when exposed to ultraviolet light and this causes discoloration and cracking of the insulation which leads to premature failure of the cables

Recommendations

Cables should be protected from direct exposure to sunlight Future modifications to switchyard or new installations should specify running these cables out of the trench and into the control cabinets via conduit

6 1 7 2 Installation

Observations

- Control cables in the switchyards are designed to be run in covered concrete cable trenches at the surface of the switchyard

When cables have been replaced or added they have very often been run outside the trenches, over the lips of open trenches where the covers have been removed, over sharp edges of trenches or cabinets, and bending radii have been reduced below minimum, with tight loops in cables In general poor installation practices have been followed

Recommendations

Quality control of cable installations should be maintained Cables should be run in the trenches which were provided for them They should enter the trenches via conduits located on the side walls of the trench Bending radii of cables should not be less than about 13 times the O D of the cable All cable trench covers should be replaced No tight loops should be left in cables and cables should not be run over sharp edges or concrete lips

6 1 8 HV ISOLATING SWITCHES

6 1 8 1 Auxiliary Contacts

Observations

In all instances whether the Isolators were electrically or manually operated, auxiliary contacts were wired back to the control panels in the switchgear building for status indicating lights, interlocking, and semaphore indication These auxiliary contacts were mounted in small control boxes mounted to the supporting steel structures of the Isolator These boxes were corroded, had missing gaskets, could not close tightly to seal against the weather, and as such the auxiliary contact banks were corroded, terminals were corroded, and in some instances non-operational due to extensive corrosion

Recommendations

Boxes should be rust proofed, gaskets should be replaced and or renewed, closing mechanisms should be in place, and the auxiliary contacts bank itself cleaned, or replaced Cables entering the box should be through conduits with glands and all openings or spaces should be sealed to prevent ingress of moisture and/or insects lizards, etc

6 1 8 2 Thermo-vision Scans

Observations

Thermo-vision scans taken of the isolating switches showed, in some cases, overheating at the jaws due to the blades not seating properly in the jaws or due to misalignment In one instance (Karnal switchyard) there was continuous visible arcing at the jaw end of an isolating switch

Recommendations

Periodic thermo-vision scanning of the Isolator switches will help detect any hot spots due to high contact resistance at the jaw ends of these switches These hot spots should be noted, investigated, and corrected as soon as possible

6 1 8 3 Out-of-plumb installations

Observations

In some switchyards (e g Beer) the 'vertical' insulating columns of Isolator switches were badly 'out-of plumb' This indicates sloppy erection practices and could result in high contact resistance, and thus higher losses, due to bad alignment of the blade and jaws

6 1 9 STEEL STRUCTURES

6 1 9 1 Painting vs Galvanizing

Observations

It was obvious to visually see the difference between 'painted' structures and 'galvanized' structures All the painted structures had lost their paint a long time ago and were badly corroded The galvanized structures held up a lot better with time Some galvanized structures had permitted the use of 'black' bolts and these bolts were very badly corroded while the structure itself was intact Conversely 'painted' structures using galvanized lots had the structures corroded while the bolts were all in tact

Recommendations

On all future jobs, galvanized structures with galvanized bolts should be specified A cost evaluation should confirm this choice as replacement of rusted structures could be cost prohibitive

6 1 9 2 Bolts vs Welding

Observations

In the switchyards where ganged single pole SF6 breakers were used, the linkage between poles for simultaneous operation of all 3-poles is critical The manufacturer therefore specifies and supplies welded structures

On welded structures the steel structure ground connection need only be made from the base of the structure to the ground grid In bolted structures however the connection to ground from the mounted equipment should be a metallic bar running from the equipment to the ground grid with no reliance on the 'bolted' structure to carry the ground current

Recommendations

Bolted structures must have continuous metallic ground conductor from the equipment mounted on the structure to the ground grid with no reliance placed on the 'bolted' connection to carry ground current

6 1 9 3 Bolts, Corrosion

Observations

Bolts used with galvanized steel structures were corroded while the structural steel showed no signs of rusting

Recommendations

Either galvanized bolts were not specified, or the contractor was not supervised closely enough to prevent him from using 'black' bolts in lieu of galvanized bolts

Galvanized bolts must always be used with galvanized steel structures

6 1 10 OUTDOOR CABINETS & MARSHALLING KIOSKS

6 1 10 1 Gaskets

Observations

In nearly all the switchyards visited, the weather sealing gaskets had hardened had lost their resilience, were badly cracked, or were missing in strips As a result they did not form a continuous seal around the doors of cabinets to seal out the weather

Recommendations

Suitable gasketting material should be purchased in rolls, gaskets cut to length, and applied with a suitable adhesive along the lip of the door opening Replaced gaskets

should be checked periodically for pliability and resilience and should be replaced again when needed Gaskets should not be allowed to deteriorate beyond their effectiveness

6 1 10 2 Corrosion

Observations

Many of the outdoor cabinets and kiosks are very badly corroded as are the hinges and doors The paint is peeling and the inside bottom plates are also corroded due to leakage of water into the cabinets through faulty gaskets

Recommendations

Cleaning and painting with an anti-rust (rust inhibitor) paint to stop further corrosion is recommended

6 1 10 3 Cable Entry

Observations

Holes punched in the bottom plate of the cabinets allow cables to enter the cabinet Cables enter through the holes which may or may not have bushings Unused holes are left open Cable connectors may or may not be ring-tongue type

Recommendations

Unused holes should be sealed All cables should enter the holes and all holes should be furnished with bushings After the cables are passed through the bushing, the bushing should be sealed with a mastic to eliminate the open space between cables of the same bushing

On new installations the cables should be run in conduit to the bottom of the cabinet and the conduit should enter the cabinet at a gland The gland should be sealed with mastic after the cables are installed All cable connectors should be specified to be of the ring-tongue type This gives a positive, reliable, vibration fee, connection

6 1 11 CABLE TRENCHES

6 1 11 1 Covers

Observations

The trenches with covers are well designed But in many instances, covers are broken, covers are not in place, or covers cannot be put in place because cables have been exiting the trench over the lip of the trench

Recommendations

Replacement covers can be cast in place, as was seen at one of the switchyards All broken and missing covers should be replaced Cables entering over the lips of trenches should be properly routed through conduit sleeves on the wall side of the trench, allowing the top covers to be inserted to cover the trench

6 1 12 CONNECTORS

6 1 12 1 Thermo-vision scans

Observations

Thermo-vision scanning of the switchyard at peak load conditions pointed out hot spots and overheating, particularly at connectors Once these 'hot spots' were determined the cause was or should be investigated

Hot-spots are a result of high I^2R losses due to high contact resistance in the connector In many cases bolts were missing, bolts were corroded, connectors were incorrectly applied, connectors were the wrong size, and/or connectors were not bi-metallic when they should have been

Recommendations

To reduce the contact resistance of a connector the following should be considered -

(i) Metals being connected Is bi-metal connector required?

(ii) Configuration of conductors being connected

(iii) Ampacity or size of connector

(iv) Fasteners to obtain the required contact pressures for low resistance

After considering the above requirements, choose the correct connector for the application and once installed take thermo-vision scans again and be satisfied that the hot-spot has now been eliminated

Periodically re-scan the connectors to ensure that no corrosion is building up or that contact resistance is not increasing

6 1 13 JUMPERS

6 1 13 1 Installations

Observations

In many instances the wrong configuration connector was used with a jumper e g a horizontal jumper between a CT and a breaker had a vertical connector on the CT and a horizontal connector on the breaker Since the horizontal spacing between the CT and breaker was limited the jumper had to take off vertically from the CT with a very sharp bend in it to bring it into the horizontal plane to connect with the horizontal connector on the breaker Limited horizontal spacing resulted in a very sharp bend in the jumper, way less than the minimum bending radius of the jumper cable This damages the cable Also when making tight bends in jumpers the stands on short lengths of cable tend to 'open' out, again resulting in hot spots

Recommendations

Use the correct connectors for the configuration of conductors to be connected Do not shave strands off the jumper to fit the connector The connector should fit the jumper

6 1 14 MV CAPACITORS & CAPACITOR BANKS

6 1 14 1 Fuses

Observations

By design, individual capacitors in the banks are individually fused In many instances however, fuse wires have melted and have not been replaced, which means that the 'available' capacity has been depleted by the opened fuse units

Recommendations

Correctly fuse all the units in the bank so that the full potential of the capacitor bank is available and maintain the replacement of all fuses

6 1 14 2 Isolating Circuit Breakers

Observations

In some switchyards the circuit breaker connecting the capacitor bank was defective and out of service As such the capacitor banks could not be utilized at all

Recommendations

The HVPNL operating staff must have access to breaker spare parts and or replacement circuit breakers Any needed spares or equipment should be listed as such in the "Needed Equipment logs" which must be updated by the SSE and sent in as needed to HVPNL management The needed breaker should be repaired or replaced on a high priority basis so that the crippled capacitor bank could be put back in service as soon as possible

6 1 14 3 Switching Control

Observations

Capacitor banks at present are located only at select switchyards Switching of the banks is done purely on a manual basis guided by operator judgment or some type of prior verbal instructions given to the operator Not all associated power factor meters, voltmeters, and ammeters were operational

Recommendations

Consistent, written operating instructions should be given to each operating switchyard that contains capacitor banks Instructions should be placed on a chart and be available in the control rooms at the capacitor bank breaker for any operator to be able to follow

The operator must be given the information that enables him to decide when and how to switch the banks on and off

All associated indicating instruments must be made functional and accurate Power factor meters, voltmeters and ammeters must be calibrated and functional

6 1 14 4 Surge Protection

Observations

Capacitor banks like distribution transformers need to have lightning arresters for surge protection These have not always been provided

Recommendations

All capacitor banks must have lightning arrester mounted as close to the capacitor bank as possible At the switchyards, station class arresters must be used

6 1 15 MV METAL-CLAD SWITCHGEAR & CONTROL PANELS

6 1 15 1 Circuit Breakers

Observations

- Operation counters on the circuit breakers are not being utilized by the O&M staff of HVPNL
- Mechanical Targets or Flags on a number of circuit breakers are either damaged, missing, bent, or non operational
- The electrical charging circuits of a complete line-up of switchgear breakers (Beer switchyard) are non-operational Each breaker has to be charged manually with a charging handle
- The SCMVA or interrupting capacity of the 11 KV breakers (at Beer switchyard) are not shown on the nameplate How does one determine the adequacy of this switchgear to withstand or interrupt faults?

Recommendations

- Maintenance on the breakers must be performed as required in the O&M manuals, according to the number of operations performed as read on the counters

- All mechanical targets must be repaired or replaced to give proper indication of breaker status

- The breaker control circuits must be trouble-shot and the faulty non operation of the electrical charging circuit must be corrected

- SCMVA of the breakers must be traced back to supplier and purchase order and must be shown on the breaker nameplate This is a standard requirement of switchgear

6 1 15 2 Control Equipment

Observations

- Ammeters Many instruments are not working and confidence cannot be gained whether a breaker is closed or not, just from taking the ammeter reading

- Power factor meters These are used to switch on or off the capacitor banks, but many of these instruments are not working Also a defective meter does not register zero, but instead registers anywhere on the power factor scale such as 0 9 lag, giving one the false impression that it is reading accurately!

- Current Transformers All locations have multiratio CT's but CT ratios were not available and what ratio was actually connected was not available As such there is no way to determine what amps or power the circuit is taking by looking at the dual range ammeters or energy meters

- Indicating lights Nearly every breaker has associated with it five colored indicating lights as follows -

Red	-	Breaker Closed
Green	-	Breaker open
Blue	-	Springs charged
Amber	-	Protective Trip
White	-	Trip circuit Healthy

In nearly every switchyard the majority of these lights were not functioning At Babyal switchyard not a single indicating light was functioning

Lack of correctly operating indicating lights, ammeters, and breaker targets, sometimes all on the same circuit, makes the operation of the switchgear "operator unfriendly"

As an example, at Babyal switchyard

(i) On one 11kV feeder

- Breaker lights were burnt out
- Feeder ammeter was defective
- Breaker ammeter target was missing

Yet the breaker was "closed" and the circuit was ENERGIZED

(ii) On an adjoining 11 kV feeder

- The red light was off Breaker lights were burnt out
- Ammeter had a slight positive reading (It could have been zero error)
- Breaker target said "OFF"

Yet the breaker was "ON" and the circuit was ENERGIZED

Recommendations

- All defective ammeters and power factor meters must be replaced HVPNL management must set up a system whereby faulty instruments must be replaced, and repaired if possible

- A lot of progress has been made with depicting available CT ratios on each panel and underlining the connected ratio The HVPNL trainee's were quick to see and appreciate the need for this

- Indicating lights still seem to be a problem in that bulbs are not available or money to purchase bulbs is not available Whatever the reason, it is of paramount importance that HVPNL management offer guidance to the switchyard SSE's how these bulbs are to be obtained, as operating a system with no indicating lights could lead to dangerous, unsafe situations

6 1 16 MIMIC BUS & HV CONTROL/RELAY PANELS

6 1 16 1 Mimic Bus

Observations

- Mimic buses in the various switchyards did not seem to comply with an assigned color code for the various voltage levels Also in some switchyards (eg Pinjore) the same voltage level bus had different colors, one portion was pink, the other portion was purple
- The mimic has configuration did not follow the actual switchyard physical configuration

  (i) Double buses were shown when only a single bus existed (e g Nilokheri switchyard)

  (ii) Incoming circuits where no incoming breaker was used, were not depicted at all on mimic buses (eg Beer switchyard)

  (iii) Outgoing and Incoming circuits were not depicted with "arrows" pointing in the appropriate direction of power flow, or, were pointing in the wrong direction (e g 132/33 kV bus at Beer switchyard)

  (iv) Mimic buses continued along the length of the panels did not line up Some panels had the buses at the top and others showed the same bus at the middle level on the adjacent panel (e g Nilocheri switchyard)

Recommendations

- The mimic buses must have specific colors corresponding to their voltage levels, as per an HVPNL formulated standard
- The mimic bus must be an exact and accurate representation of the physical bus arrangement in the switchyard

6 1 16 2 Semaphores

Observations

In 90 per cent of the switchyards reviewed, the semaphores on the mimic bus of the control panels were non-operational In double bus installations with selectable isolators for a transformer or feeder circuit, the isolator semaphores were in the 'open' position, the breaker semaphore was in the 'open' position and yet the breaker red indicating light was "ON" indicating the circuit was 'alive' The circuit could only be alive if either one or both of the isolator semaphores were closed, and the breaker semaphore was in the 'closed' position

The purpose of the mimic bus and semaphores is defeated if it does not depict to the operator the current status of his equipment At one switchyard (Beer, 132 kV) the semaphore was functional but it had been wired incorrectly It depicted 'open' when actually the isolator was closed and vice versa. This is a dangerous situation

Recommendations

All semaphores must be made functional and must be correctly wired

6 1 16 3 Indicating lights

Observations

As with switchgear control panels, here too indicating lights were non-functional due to burnt out bulbs not being replaced

Recommendations

All indicating light bulbs must be replaced immediately on burn out Stocks of bulbs must be made available to each and every switchyard It appeared that some SSE's had better and faster access to spare bulbs, whereas others had absolutely no way of obtaining spare bulbs (eg Babyal) The policy should be uniform throughout HVPNL

6 1 16 4 Indicating Instruments

Observations

Many ammeters, and some voltmeters too are non-functional

Recommendations

All non-functioning instruments should be replaced immediately The defective instruments should be returned to an HVPNL test facility for repair and re-calibration and returned to stock

6 1 16 5 Cover Plates

Observations

In some instances provision had been made for future relay installations, or cutouts for relays/instruments/switches have been left 'open' because the original openings now did not fit the replacement used Metal cover plates had not been used to cover any openings In one instance (Nilokheri) a piece of paper had been pasted over the opening but subsequently a hole had been poked into the paper cover thereby tearing the paper and defeating its purpose as a 'cover'

Recommendations

All 'openings' or 'cutouts' in panels must be covered with metal plates to prevent entry of insects, lizards, geckos, rodents, etc into the panels

6 1 17 STATION BATTERY

6 1 17 1 Fuses

Observations

Not all switchyard batteries had fuse protection at the battery terminals Surprisingly, this was the case in newer, larger, more recent switchyards such as Pehowa, whereas in some older, smaller switchyards such as Babyal, new porcelain fuse holders/fuses had been installed

Recommendations

The protection of the battery cables from the battery to the charger/dist cabinet is essential As such suitably sized, wall mounted porcelain fuse holders with withdrawable fuses must be provided at the leads from the battery In the event of a cable fault, these fuses would protect the battery from discharging into the fault and eventually destroying itself

6 1 17 2 Cell Monitoring

Observations

The battery is the 'heart' of the entire switchyard and must be maintained at all costs Further, replacement batteries are expensive and have long 'lead times' before they can be made available It is crucial that the battery condition be monitored and checked in order to prevent any catastrophic, sudden failures To achieve this the following must be done -

- Specific gravity checks on each cell must be performed on at least a weekly basis
- Periodically the batteries must be examined for physical damage to the cells, containers, racks, connections, etc
- Cell voltage checks under load conditions must be performed regularly
- Battery fuses must be checked to ensure they are not 'blown'
- Other O & M manual required checks

Recommendations

All the above checks that are mandatory must be kept in a log so that any deterioration of the battery can be monitored and timely corrective action can be taken to ensure that the switchyard has a healthy battery at all times

6 1 17 3 Battery room exhaust Fan

Observations

Lead acid batteries off gas hydrogen which is a flammable gas As such all battery rooms are provided with exhaust fans In some switchyards, the exhaust fans were missing from their location (eg Beer), while in nearly 100 per cent of the others the exhaust fan was turned off

Also in one switchyard, the battery room was being utilised to prepare tea, using an open hot plate, to boil the water This particular location did not even have an exhaust fan

Recommendations

All battery rooms should be provided with exhaust fans and the exhaust fans should be running 100 per cent of the time

6 1 17 4 Eye wash & shower

Observations

Battery acid spillage is a common occurrence in any battery room and OSHA requirements in the USA have mandatory requirements for an eye wash station and body shower facilities to be provided All switchyard battery rooms have No wash facilities

Recommendations

The absence of eye wash stations and showers is probably due to economic constraints However some type of wash facilities must be provided in a battery room This could be satisfied by one of the following -

- Portable eye wash station
- Buckets of water filled with water at all times being available in the room
- A hose connection to a water pipe from outside with water available at all times from the hose, and control of the water from inside the battery room

6 1 17 5 Battery Grounds

Observations

There was an interesting phenomena that was present at the Madhuban switchyard battery It is important to single out for comment because it is a very serious situation

Using a voltage test light, connecting to the negative terminal on the battery caused the bulb to glow Connecting to the positive terminal caused no glow

The second noticeable scenario was that when the charger was switched off the output voltage of the battery dropped from 220 Vdc zero in a few seconds, indicating the battery could not hold a chanre and was completely depleted

Recommendations

The 'glow', 'no-glow' scenario seems to indicate a ground on the positive lead of the battery, since all healthy HVPNL's batteries are floating, with no intentional ground on them

The second scenario is a lot more disturbing since it indicates a 'dead' battery which probably could never get charged due to a ground on the positive and a high resistance ground on the negative

In this station if ac supply to the charger ever fails during, before, or after a fault, the station has no protection at all, since the battery output voltage is zero!

This station should be thoroughly investigated and suitable corrections made to alleviate the situation

6 1 18 SWITCHYARD MAINTENANCE

6 1 18 1 Maintenance Logs

Observations

Maintenance logs are not being kept on a standardised or comprehensive basis for each switchyard It is left up to the individual SSE's to prepare, if at all, their own logs See Appendix IX where a very commendable effort had been made by the SSE of Nilokheri Switchyard to formulate a comprehensive maintenance program for his switchyard

Recommendations

HVPNL management must lay out uniform, standardised requirements for the preparation of all logs that must be kept at each switchyard, outlining the periodicity and the items to be checked, measured verified noted, etc

6 1 18 2 Maintenance Schedule

Observations

Again, the only visible effort that maintenance schedules were in existence at any switchyard was the exhibit shown in Appendix IX to this report
The maintenance of equipment is unique to the manufacturer and as such generic schedules cannot be prepared for each type of equipment The schedules must be based on the O&M manuals supplied by the specific manufacturer of the specific equipment The manufacturer knows his equipment best

Recommendations

O&M manuals for every piece of equipment in the switchyard on must be available at the substation to the SSE of that particular switchyard

HVPNL needs to issue maintenance schedules for each switchyard based on the O&M manuals of the manufacturers who supplied equipment for that particular switchyard

Incorporated into these schedules should be HVPNL's standard practices and procedures, together with "Indian" and "Local" practices

These schedules should be then maintained at each switchyard and periodic or daily logs prepared, performed and kept for future reference to determine the full operating and performance history of each piece of equipment

6 1 18 3 Spares/Replacements

Observations

There appears to be no formulated policy or procedures in place at HVPNL for switchyard SSE's to report, obtain, and install needed replacements and/or spare parts

Needs may be for daily expendable items, like bulbs, major items, like HV circuit breakers, and long lead items, like 'station' batteries

Recommendations
It is imperative that procedures are set up to do this, as many installations are operating in very unsafe conditions due to the lack of spares, replacement parts, and even replacement equipment (eg HV circuit breakers, at Babyal switchyard)

6 1 19 SAFETY

6 1 19 1 Temporary Situations

Observations

Safety in some instances is sacrificed due to the fact that the situation is 'temporary'

Recommendations

'Temporary situations' is no excuse for the adoption of unsafe practices Murphy's law states, "If something can go wrong, it will" and this is usually the case Safety must be observed in all, and each and every instance

6 1 19 2 Safe Practices

Observations

- Switchyard personnel have no written standardised safety procedures to follow
- 'Tagging' of equipment removed from service appears to be 'optional'
- Authorization for shutdowns appears to be at an engineers individual discretion He is not held accountable to a Manager
- Outgoing feeders at H structures are not identified with the metal-clad breakers that control them in the control building
- MV cables connecting metal-clad breaker to the H-pole overhead lines are not "capacitive discharged" when outages are taken on feeder lines
- No ground chains are used to initially ground a feeder before working on it Reliance is placed on the circuit breaker being opened
- A "ground connection" is made to the overhead line, by the lineman connecting a ground lead to the line with his bare hands The assumption here is that the correct breaker has been opened and racked out to isolate the line and that the MV cable has discharged itself over a period of time (allowing about 10 minutes), and that there is no backfeed down the line from the remote end These are a lot of assumptions!!!
- Lineman don't use safety belts
- Faultsman don't use gloves when operating with hot sticks
- Proper lifting tackle is not used when lifting heavy loads or when in preecarious positions or locations

- No head protection or foot protection is observed (or eye protection, or ear protection, in special instances)
- No cordoning off or taping off of HV work areas or test areas, is observed
- Tagging of equipment is not mandatorily observed
- Work permit issuance is not observed
- Flashlights or battery lanterns are not available at switchyards for emergency operations during outages
- Wash water facilities are not available in battery rooms

Recommendations

Safe practices must always be observed and especially during -

- Construction
- Planned outages
- 'temporary' situations
- emergency situations
- maintenance operations
- Testing
- Switching
- Normal operations
- Switchyard Walkdowns

"Safety" never has an off day and live circuits and voltages must always be treated with respect

Safety equipment must be used at all times such as grounding chains, linesman s belts, rubber gloves, etc

Safety procedures, specified in writing by HVPNL management must be followed at all times This is mandatory and not optional

Safety equipment must be furnished by HVPNL management to all personnel

Logs must be kept of all planned outages, fault outages, and tripping out of circuit breakers for whatever reason Here again, excellent records in chart form had been prepared and maintained by SSE at Nilokheri switchyard

6 2 DISTRIBUTION SUBSTATIONS

6 2 1 DISTRIBUTION TRANSFORMERS

6 2 1 1 Fuses

Observations

- In theory HVPNL protect their distribution transformers with fuses on the HV and LV sides In practice however a "wire strand" is used for the HV side fusing and a cable "wire strand" is used for the LV side fusing Both of these "fuses" are uncontrolled and have unknown melting characteristics, and wire strand size selection is up to the individual lineman or engineer

- No attempt is made to co-ordinate the HV "fuse" characteristic with the "Inrush current curve of the Transformers" or with the "Thermal Withstand current curve of the Transformer"

- The "fuse" characteristic curve is totally unknown, and in practice if the transformer inrush current blows the "fuse" then a larger size "fuse" wire is selected, until it can withstand the transformer inrush current without blowing

- Similarly on the LV side one or two stands of the multi-stranded LV cable are used as "fuses" This selection is purely arbitrary and the "fuses" may not protect the transformer thermally Over sizing these "fuses could also destroy the transformer thermally

Recommendations

HVPNL design department must examine and be responsible for the selection co-ordination, and specification of all fusing to be used on distribution transformers of all sizes

Incorrect and haphazardly chosen "fuses' by the operations staff has resulted in thermal burn out of way too many distribution transformers See principles of co-ordination that must be observed as outlined in Appendix II Investment in correct fusing and their application will help offset the expenditure on replacement of burnt out transformers and the building of more and more repair facilities which are being overloaded with work

The proper co-ordination of fuses with "Inrush" and "Thermal withstand" curves cannot be overstressed enough It is of prime importance in reducing transformer failures See also Appendix VIII

6 2 1 2 *Overvoltage Protection*

Observations

On many distribution transformer installations, lightning arresters are not installed, or are not connected, or are non-operational

Recommendations

It is mandatory that every distribution transformer substation be provided with healthy lightning arresters on every phase, and that they be connected properly into the circuit at the interface of the transformer HV bushings with the overhead line
Grounding connections of the lightning arresters must have a metallic connection to the transformer tank and neutral (see lecture notes in Appendix II)
Lightning arresters must be checked periodically for operability, and verification that they have not been exhausted by excessive discharges Absence of lightning arresters at distribution transformers could lead to overvoltage failures

6 2 1 3 Repair Facilities

Observations

A repair crew in Karnal was observed where 'repairing' a distribution transformer whose leads had burnt out The transformer windings and core had been untanked by hanging a block and tackle from a tree branch and suspending the coils/core outside and above the tank The broken (burnt out) lead was apparent The broken connection was 'repaired' by twisting the two broken ends together and the transformer was then re-tanked No copper brazing was utilized No oil integrity checks were carried out when the transformer was re-tanked

Recommendations

Firstly, twisted connections give rise to high I^2R losses so the efficiency of the "repaired" transformer is greatly reduced This could also lead to a "hot spot" within the transformer and on heavy loads could cause another burn out of the connection

A proper repair under controlled conditions should have been carried out Connections should be done, such as use of brazing, in making copper to copper connections The original integrity and electrical parameters of the transformer must be maintained even after the repair Oil contamination after untanking is also a factor to be considered

Also with reference to Section 6 2 1 1 proper fusing of distribution transformers would result in less burn out of units and thereby less importance would need to be placed on adding more repair facilities

6 2 1 4 Maintenance

Observations

Distribution transformers, since they are generally pole mounted on H-frames above ground, don't receive any maintenance checks This is due to their location being inconvenient for ready accessibility

Regular checking of oil levels, silica gel replacement, or oil withstand tests on samplings are not carried out routinely Thermo-vision scanning of the transformers periodically for overloading conditions is not carried out either

Recommendations

Transformers must be monitored periodically for overload conditions and changed when load conditions demand it Turning a "blind eye" to overloading will not correct the situation and this will eventually lead to transformer burn out

Maintenance as required by the manufacturer in the O&M manuals must be observed Periodic oil level checks, silica gel replacement when saturated, and voltage withstand tests on oil samples, must be carried out Correct, efficient repair of transformers is mandatory

6 2 2 LIGHTNING ARRESTERS

6 2 2 1 Connections in Circuit

Observations

- Lightning arresters are not always connected at the interfaces of
  - (i) distribution transformers with overhead lines
  - (ii) cables with overhead lines
  - (iii) capacitors with overhead lines
- Lightning arresters are not always connected to ground correctly See lecture notes in Appendix II
- On distribution circuits distribution class arresters need to be used
- No checks are done to ensure lightning arresters are not exhausted and are effective and healthy

Recommendations

- Distribution class arresters must be used at all interfaces of

  (i) Distribution transformers with overhead lines

  (ii) Cables with overhead lines

  (iii) Distribution line capacitors with overhead lines

- The ground connection of lightning arresters must have a metallic connection also to the transformer tank, and the transformer neutrals This metallic connection could be below ground level

- Maintenance logs must be kept on all lightning arresters so that they are replaced when they are exhausted or cease to be effective

6 2.3 FUSES

6 2 3 1 Type

Observations

- Bare wires, sized arbitrarily by the faultsman or engineer, are used in lieu of fuses that have predictable characteristic curves

- The only co-ordination done is to put a large enough wire stand in lieu of the fuse to enable the transformer to draw inrush current without blowing the "fuse"

- "Fuses" are isolated for replacement by the use of a manually operated line disconnect switch upstream of the "fuse"

- Replacement "fuses" are arbitrarily selected at the discretion of the faultsman or engineer and have no theoretical basis

Recommendations

- HVPNL's meter and relay design group should pre-select the correct fuses to use with each size of distribution transformer This information must be distributed to all distribution engineers and faultsman These standardized fuses must then be purchased and stocked as standard items to be drawn or by the distribution engineers when required

- The use of 'D' type (i e Drop-out-type) fuses are recommended in place of the open wire fuses/isolating switch combination Most isolating switches in-service are inoperative anyway The proposed D fuses provide the isolating means built into the fuse holder and is a more economic and maintenance free

device This should be considered on all new distribution substations as a design requirement by HVPNL

- Replacements for the standardized fuses selected must be available to all HVPNL Distribution Engineers and Faultsmen

6 2 4 ISOLATING SWITCH

6 2 4 1 Functionality

Observations

- Many Isolating switches are badly corroded, have linkages missing, and have misaligned contacts

- Switches are not padlocked out and are open to vandalism or misoperation by unqualified personnel

- Switches are used to isolate the distribution transformers for replacement of fuses

- Also sometimes these switches are used in a feeder circuit to dump 3-phase loads in the event of overloads occurring in a feeder during certain periods of the day or night In dumping the 3-phase loads the switches are wired to pick up all the single phase loads existing on 2 phases only This is done to alleviate the 3 phase overloading on the feeder (HVPNL policy)

Recommendations

- The isolating switches must be properly maintained and must be padlocked to prevent unauthorized operation by unqualified personnel

  As an option, on new installations 'D' fuses are recommended to replace the open fuse/isolating switch combination

- The policy of alleviating 3-ph overloads by picking up single phase loads on 2 phases onto 1-phase should be abolished, the practice leads to highly unbalanced loads and this leads to higher I^2R losses since unbalance currents flow back through the neutral wire (See lecture notes in Appendix II) Other means should be designed to prevent 3-ph overloads on feeders

6 2 5 CONNECTORS

6 2 5 1 Wire Wraps

Observations

HVPNL uses manufactured connectors in all their 220 kV, 132 kV, 66 kV and 33 kV switchyards and substations At 11 kV no connectors are used Instead, all connections are made by "wire wraps" (i e connecting two conductors together by wrapping a binding wire around the two conductors which are positioned side by side) Thermo-vision scans taken at night indicate that all wire wraps produce "hot-spots", many in excess of 120°C Some connectors were actually burning (visible arcing) during periods of heavy loads

Recommendations

The prime purpose of a connector is to provide an electrically continuous path from one conductor to the connected conductor, with the lowest possible resistance and therefore with the lowest I^2R losses

With "wire wraps" the contact resistance is high and also cannot be controlled or predicted As such, wire wraps should be replaced with manufactured connectors that are correctly designed for the application they are to be used in See lecture notes in Appendix II for correct selection of connectors

6.2 6 OVERHEAD SHIELD WIRE

6 2 6 1 Installation

Observations

HVPNL practice is not to install overhead shield (or ground) wires above the distribution lines (11 kV & 33 kV)

However, all HV Tower lines (66 kV, 132 kV, & 220 kV) and Switchyards contain the overhead shield wires

Recommendations

On distribution substations therefore where there is no overhead shield wire reliance is placed on the lightning arresters at the substation to take care of any surges or direct stokes coming down the line

6 2 7 OPERATING PRACTICES

6 2 7 1 Unbalanced loading

Observations

On many 3-ph lines the loading is unbalanced and this is compounded further by having 1-ph lines radiating out from the ends of 3-ph feeders Not much effort is put into trying to balance the loading on these feeders, under normal operation Close balancing would reduce the losses

Recommendations

Unbalanced circuits lead to currents flowing in the neutral conductor and this increases the losses Line loadings must be analyzed and balancing of phase loadings must be adjusted to be within 10 per cent

6 2 7 2 3-ph to 2-ph connections

Observations & Recommendations

In this regard, see the relevant paragraphs in Section 6 2 4 1 This switching which dumps 3-ph loads helps to alleviate the problem of overloading but in doing so introduces the problem of unbalanced loads which increase the losses

6 2 7 3 Overloaded Transformers

Observations

No monitoring of transformer loads is carried out on a routine basis Many distribution transformers are overloaded as are LV cables Thermo-vision scans depict this

Recommendations

Overloaded transformers should be replaced with those of higher capacity and/or loads should be re-arranged amongst the transformers available to keep all transformers within their full load limits

6 2 8 CONSTRUCTION PRACTICES

6 2 8 1 Stays on H-Poles

Observations

- In many instances the turnbuckles on stays have not been tightened and the H-frames lean into the tensioned lines
- In some instances, at angle poles the stays have not been positioned correctly to bisect the angle of pull Thus, the poles again lean into the tensioned lines

Recommendations

All stays must be correctly tightened and tensioned, and stays must be correctly located and positioned

6 2 8 2 Grounding

Observations

Not too much attention has been paid to observing correct grounding practices and achieving low resistance grounds at the individual distribution substations

Recommendations

Ground grid resistance must be reduced to less than 1 ohm by driving one or more ground rods as required, or running a larger ground mat

All equipment required to be grounded must be connected to this ground mat See lecture notes in Appendix II

6 2 8 3 Isolation on LV side

Observations

No means of isolating the LV circuits at the transformer have been provided It is HVPNL practice to connect the LV cable to the LV bushings of the transformer by a single or double strand wire fuse The open wire fuse is mounted on a wooden board which is strapped to one leg of the H-frame structure at anywhere from 3 ft to 5 ft above the ground These are bare, open wires operating at a voltage of 415V 3 ph, 60 Hz To replace these LV "fuses" one has to operate the HV side manual isolating switch The 415V wires are bare, exposed, at low height with no warning boards, danger boards, barriers or enclosures, around them They are within easy reach even of children, or animals too, in certain locations In one instance this 415V exposed circuit was at the base of an H-pole in the corner of a playing field and the H-frame acted as the goal posts for the kids playing soccer (in Nilokheri area)

Recommendations

This practice of exposing 415V bare conductors within approximately 4 ft off the ground is highly dangerous The conductors should not be exposed, should be inaccessible to human touch, and should have a safe means of isolating the LV circuit Thus the LV cables from the transformer should be brought into a ground mounted feeder pillar which should contain porcelain fuse holders/fuses inside it Access into the feeder pillar should be only through a front door which is lockable Only HVPNL personnel should have the keys for access, and the feeder pillar should be vandal proof No exposed bare, live, metal should be accessible throughout the LV circuits

6 2 9 SAFE PRACTICES

6 2 9 1 Transformer LV Connections

Observations & Recommendations

This s covered in Section 6 2 8 3 above

6 2 9 2 *Anti-climbing guards & Danger Plates*

Observations

In 99 per cent of the cases no anticlimbing guards, danger plates, or fencing had been provided at Distribution Transformer substations

Recommendations

This is even more significant in lieu of the fact that 415V exposed, live circuits are accessible and within reach 3 to 5 feet from the ground

Anti-climbing guards, danger plates, and fencing must be provided at all accessible substations Human life must be protected

6 3 DISTRIBUTION LINES

6 3 1 CONDUCTOR SIZES

6 3 1 1 Load Growth

Observations

Planning, design and construction of distribution lines does not appear to be well planned or standardized

Recommendations

The distribution system planning computer program (DPA/G) which was demonstrated by IRG to the trainees presents a well planned standardized method of planning distribution systems and their expansion

A complementary copy of this software will be presented to HVPNL by USAID, and IRG personnel will instruct HVPNL on the implementation of this program

6 3 2 CAPACITOR PLACEMENT

6 3 2 1 *On Overhead Lines*

Observations

At present no capacitor placement is made on overhead lines The only capacitor banks provided are at the switchyards themselves where they can be manually switched to improved power factor at the station bus

Recommendations

The DPA/G program selects the optimum locations and sizes of the capacitor banks required to improve voltage and power factor, and reduced losses

HVPNL Planning Dept should utilize this program for all future designs and planning

6 3 2 2 *Switching*

Observations

Presently no capacitor banks are installed on overhead lines However, when they are, thought has to be given on how they are to be switched on and off as the load varies and the power factor varies

Recommendations

Switching should probably be based on a timer which is set to switch the capacitors on and off depending on the load profile at the node where the capacitors are to be installed

6 3 3 OPERATING PRACTICES

6 3 3 1 *3 ph to 2 ph Switching*

Observations & Recommendations

This has already been covered under section 6 2 4 1

6 3 3 2 *Overloaded Circuits*

Observations

Presently hand calculations applied to a pre-selected line/load configuration indicates whether circuits are overloaded This is a laborious method of proceeding with design or re-design and is very inefficient

Recommendations

Using the DPA computer program, a click of the mouse gives all the critical parameters for selected changes in the system configuration Hence optimum design can be achieved and selected in a matter of minutes Circuits can be redesigned so that no overloading occurs

6 3 4 OVERHEAD SHIELD WIRE

6 3 4 1 *HVPNL Practice*

Observations

HVPNL practice is not to run an overhead shield wire with MV circuits Instead, HVPNL has a double wire cradle guard running under the lines to draw high ground currents in the event of a broken phase conductor touching the cradle guard This is to ensure the fast tripping of the circuit breaker or fuse to isolate the faulty circuit

Recommendations

Of much more benefit, is to run the overhead shield wire (for surge protection) and eliminate the cradle guard (The chances that the broken conductor makes contact with the cradle guard are remote)

Running an overhead shield wire would entail the mounting of an angle iron on the pole, at a sufficient height so as to give complete coverage to all 3 phase conductors when a 30 degree angle of coverage with the vertical is considered The shield wire would be affixed to the top of this angle iron mast Reuse of one wire of the 2-wire cradle guard would provide additional economies

6 3 5 CONSTRUCTION PRACTICES

6 3 5 1 *Stays on Poles*

Observations & Recommendations

Missing or incorrectly placed stays - This is also covered in Section 6 2 8 1

6 3 6 SAFE PRACTICES

6 3 6 1 *Ground Chains*

6 3 6 2 Lineman's belts

6 3 6 3 Procedures for Planned outages

Observations & Recommendations

The above three sections have been covered and included in Section 6 1 19

7 0 ON GOING IMPROVEMENTS

7 1 BY HVPNL

It is envisaged that the HVPNL trainees who have benefited from this program will go on to train their subordinate personnel, utilizing the same lecture notes presented to them at this seminar With this in mind eight (8) copies of each of the lecture notes as attached in Appendices I, II and III were left at each of the three training centres – viz Panchkula, Karnal, and Hissar

7 2 EQUIPMENT GIFTED BY USAID

In order to spread this training to benefit all of HVPNL, arrangements are being made to leave one copy of the software package DPA - Distribution Planning Analysis, and one thermo-vision scanning camera, with HVPNL for use by HVPNL personnel in further training

These tools can also be used in actual design and maintenance, thus improving the efficiency of the HVPNL electrical system USAID via IRg will gift these items to HVPNL (C/o Mr R K Jain) for safe custody and on-going usage

7 3 LOSS SAVINGS OPPORTUNITIES

It is estimated that HVPNL's T & D system energy losses total to 31 4 percent of the total energy produced, or 3993 GWh Technical and commercial losses both contribute significantly to this total This System Efficiency Training Project has focused on the loss savings opportunities available through loss saving measures including correction of "hot spots" and many other measures The table below indicates how much of the losses from each system component are can be reduced by this and other measures

Losses from each component of the HVPNL System with loss savings opportunities from each						
			Possible Reduction			
System Component	Contribution as a percent of total losses	GWH of losses	Correction of Hot spots		Other Measures	
			%	GWH	%	GWH
Generation & Transmission	33	1318	0	0	0	0
HV Substations (66 kV and above)	3	120	2	2	1	1
MV Substations (33 kV and 11 kV)	8	319	5	16	5	16
11 kV distribution lines	11	439	5	22	10	44
Distribution Transformer Substations	20	799	25	200	25	200
415 Lines (LT)	25	998	25	250	25	250
Total	100	3993		490		510
		Total Loss Savings Opportunities (GWH)				1000
		As a percent of total Losses				25 0%

It is estimated that approximately 25 0 % or 1000 GWh of the present energy losses can be saved by rigorously implementing the measures outlined in this training project

APPENDICES

APPENDIX - I

INTRODUCTION

(Lecture Notes)

IRG INTERNATIONAL RESOURCES GROUP

INDIA

SEPTEMBER 1998 – DECEMBER 1998

INTRODUCTION

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INTERNATIONAL RESOURCES GROUP
(IRG)

PRESENTATION

TO THE
HARYANA VIDYUT PRASARAN NIGAM LTD

1998

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TRAINERS

BURT HEPPONSTALL	HV SWITCHYARDS & MV SWITCHGEAR
PAUL LAVIGNE	MV & LT DISTRIBUTION LINES

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ACKNOWLEDGEMENT

ALL PHOTOGRAPHS USED IN THIS PRESENTATION HAVE BEEN PROVIDED BY MR LOUIS RODRIGUEZ OF IRG

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SYSTEM EFFICIENCY FIVE DAY SEMINAR

DAY 1	MORNING INTRODUCTION AFTERNOON SWITCHYARDS
DAY 2	MORNING SWITCHYARDS AFTERNOON TUTORIAL
DAY 3	ALL DAY INTRODUCTION TO COMPUTERS EVENING INFRARED SCANNING
DAY 4	WALK DOWN OF SUBSTATION
DAY 5	COMPUTER ANALYSIS OF DISTRIBUTION LINES AWARD OF CERTIFICATES

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BACKGROUND

RECENT TRANSFORMER FAILURES

FIVE LARGE POWER TRANSFORMERS HAVE FAILED IN THE LAST FEW MONTHS

- 1 - AT THE BABYAL S/S
  2 - AT THE HISSAR S/S
- 1 - AT THE PANIPAT S/S
- 1 - AT THE RHOTAK S/S

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PARTIAL LISTING OF SUBSTATIONS VISITED

BHORE	KARNAL
MADANPUR	BABYAL
PINJORE	HISSAR 220 kV
• HTM HISSAR	KAITHAL
SHAHABAD	PEHOWA

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USAID HVPN IRG

WHAT CAN I DO
TO IMPROVE THE
SYSTEM?

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USAID HVPN IRG

"A HUNGRY MAN
ASKS FOR FISH
TO FILL HIS STOMACH "

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USAID HVPN IRG

"TEACH HIM HOW
TO FISH &
HE WILL NEVER
GO HUNGRY"

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THIS SEMINAR ATTEMPTS
TO GIVE YOU THE TOOLS
TO HELP YOU ANALYZE
YOUR SYSTEMS &
SITUATIONS AND
IMPLEMENT THOSE
IMPROVEMENTS

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POWER SUPPLY
REQUIREMENTS & CONSIDERATIONS

RELIABLE
- EFFICIENT
- SAFE

ECONOMIC

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RELIABLE

SERVES CUSTOMER NEEDS (kVA VOLTS & Hz)
NO OVERLOADING
SPARE CAPACITY FOR FUTURE GROWTH
SWITCHING FLEXIBILITY REDUNDANCY & BACK UP
CO-ORDINATED RELAY PROTECTION
CO-ORDINATED OVERVOLTAGE PROTECTION
MOMENTARY FAULT PROTECTION (FOLIAGE CONTROL)
AUTO RECLOSERS
MAINTENANCE OF EQUIPMENT AT PEAK LEVELS
TRAINED SYSTEM OPERATORS
ECONOMIC DESIGNS
SUFFICIENT EMERGENCY CAPACITY
MINIMUM VOLTAGE
RESTORATION TIMES

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EFFICIENT

- MAINTAIN VOLTAGE & FREQUENCY
- REDUCE LOSSES
  - I OPERATING LOSSES
    - LOW VOLTAGE
    - UNBALANCED LOADS
  - II DESIGN LOSSES
    - OPTIMIZED DESIGN
    - CORRECT CONNECTORS
- ECONOMICS
- MAINTENANCE OF EQUIPMENT AT PEAK LEVELS

CONT D

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EFFICIENT

(CONTINUATION)

IMPROVE POWER FACTOR
(MAINTAIN 95% AT TIME OF SYSTEM PEAK)

BALANCED LOADING
(WITHIN 10 PERCENT)

IMPROVE VOLTAGE REGULATION

- LOCATE TRANSFORMERS AT CENTERS OF LOADS
- ADEQUATELY SIZED TRANSFORMERS

ADEQUATELY SIZED CONDUCTORS

- CONVERT 1 PHASE TO 3 PHASE TO IMPROVE BALANCING

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SAFE

PROTECTIVE RELAYING
PROPER GROUNDING
OVERVOLTAGE PROTECTION
OPERATOR FRIENDLY CONTROL & ANNUNCIATION
GLOBAL STANDARD SPECIFIED SAFE RELIABLE EQUIPMENT
MAINTENANCE OF EQUIPMENT AT PEAK LEVELS
WRITTEN SAFETY OPERATING PROCEDURES
ECONOMIC CONSIDERATIONS SHOULD NOT COMPROMISE SAFETY

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ECONOMICS

MUST ALLOW

- SAFE DESIGN
- SWITCHING FLEXIBILITY

EXPANSION FLEXIBILITY FOR GROWTH
EFFICIENCY
RELIABILITY
PLACEMENT OF CAPACITORS

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EQUIPMENT
(WITH REGARD TO RELIABLE SAFE EFFICIENT OPERATION)

- SURGE ARRESTERS
- CIRCUIT BREAKERS
- FUSES
- BATTERIES
- RELAY AND CONTROL PANELS
- CAPACITORS
- HOT SPOTS

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SURGE ARRESTERS

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SURGES OR TRANSIENTS

LARGE OVERVOLTAGES THAT DEVELOP SUDDENLY ON ELECTRIC TRANSMISSION AND DISTRIBUTION SYSTEM ARE REFERRED TO AS SURGES" OR TRANSIENTS

THESE ARE CAUSED BY LIGHTNING STROKES OR BY CIRCUIT SWITCHING OPERATIONS

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FUNCTION OF SURGE ARRESTERS

SURGE ARRESTERS PERFORM A TWO FOLD FUNCTION

1 PROVIDE A POINT IN THE CIRCUIT AT WHICH THE OVERVOLTAGE IMPULSE CAN PASS TO GROUND WITHOUT DAMAGE TO INSULATION OF EQUIPMENT

2 PREVENT ANY SUBSEQUENT FLOW OF POWER CURRENT TO GROUND BY PLACING A HIGH IMPEDANCE IN THE CIRCUIT AFTER THE EXCESS VOLTAGE IS RELIEVED

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CORRECT APPLICATION OF SURGE ARRESTERS

SA S MUST BE INSTALLED AT THE INTERFACE OF TWO IMPIRRICALLY DIFFERENT IMPEDANCES IN A CIRCUIT

E g. (I) Where O/H line terminates in a cable

(II) Where O/H line terminates on a transformer

(III) On long O/H lines at the open circuited end.

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EXAMPLES OF DEFFICIENT INSTALLATIONS

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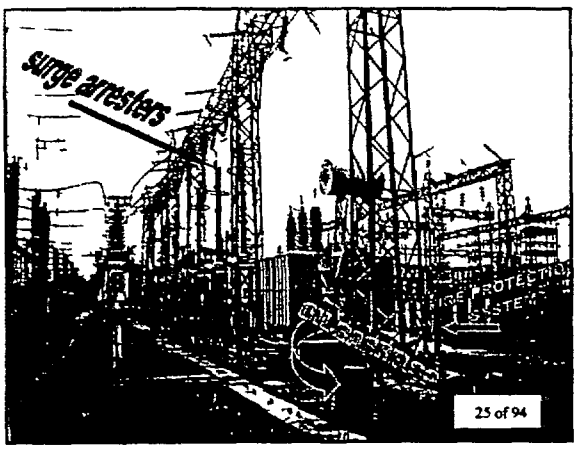

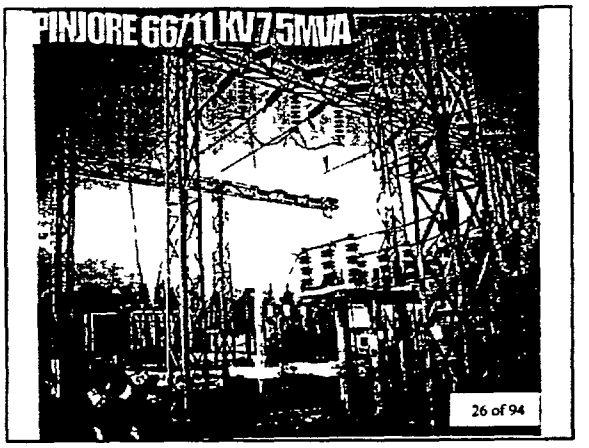

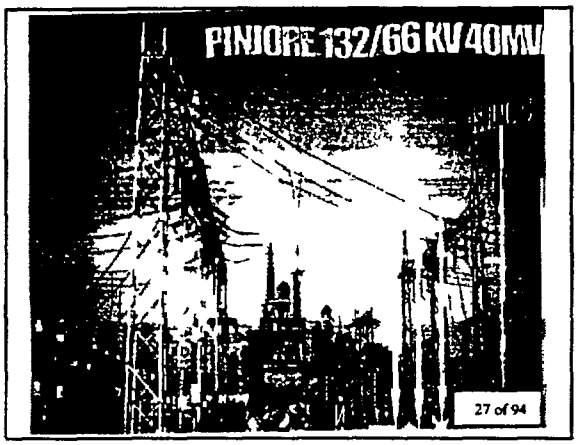

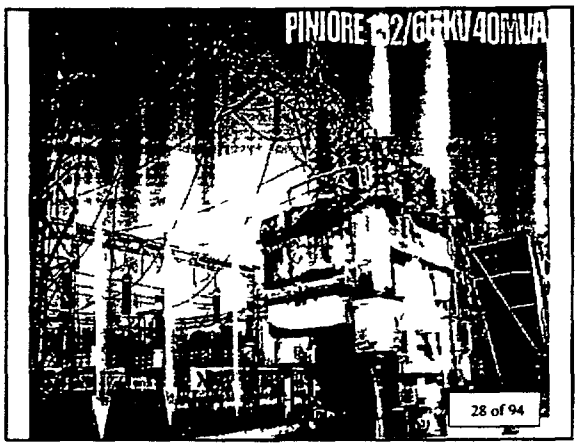

SYSTEM SURGE PROTECTION OPERATION

SA s ACT AS A SAFETY VALVE TO BYPASS OVERVOLTAGES TO GROUND AND THEREBY PREVENT THE PUNCTURING OF THE INSULATION OF EQUIPMENT ON THE LINE WHICH MAY HAVE A BIL VALUE LESS THAN THE SURGE ON THE LINE

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USAID HVPN IRG

CIRCUIT BREAKERS

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CIRCUIT BREAKERS
- GENERAL -

HAS A MECHANISM THAT MECHANICALLY HYDRAULICALLY OR PNEUMATICALLY OPERATES A SET OF CONTACTS TO OPEN OR CLOSE AN ELECTRICAL CIRCUIT

INSULATING OIL AIR COMPRESSED AIR VACUUM OR SF6 GAS IS USED AS AN ARC-INTERRUPTING MEDIUM

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CIRCUIT BREAKERS

OPERATION COUNTERS

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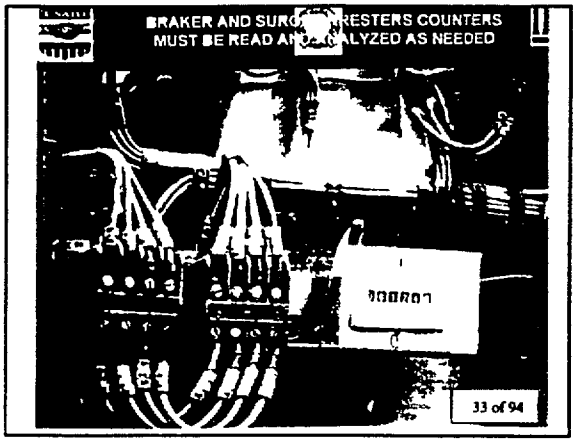

CIRCUIT BREAKERS

- EXAMPLES OF DEFECTIVE INSTALLATIONS

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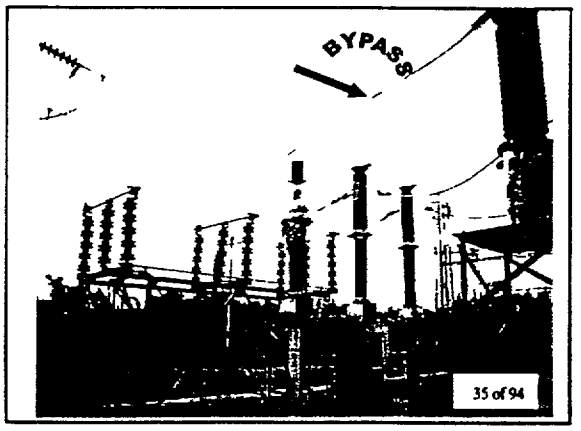

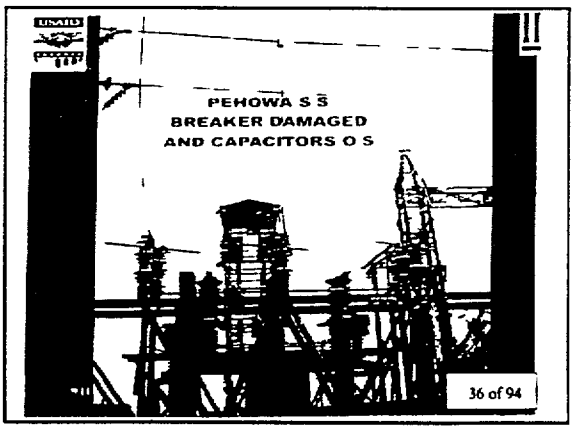

FUSES

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FUSES

- CORRECT INSTALLATION AT DISTRIBUTION TRANSFORMER

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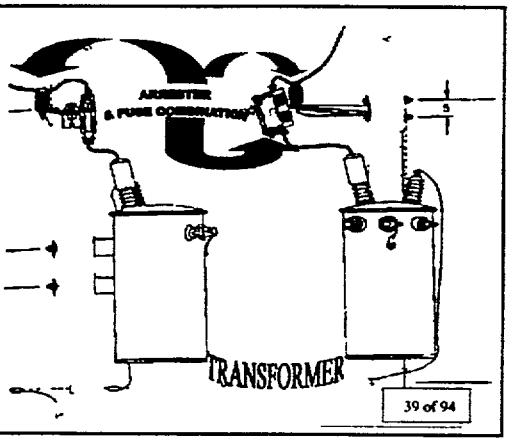

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FUSES

EXAMPLES OF DEFECTIVE/INCORRECT INSTALLATIONS

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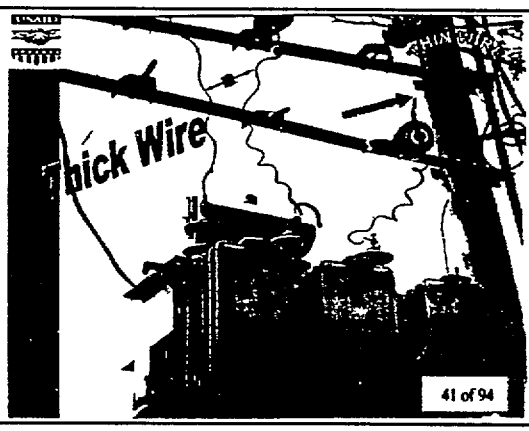

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FAILED TRANSFORMERS AT AN HVPNL REPAIR WORKSHOP

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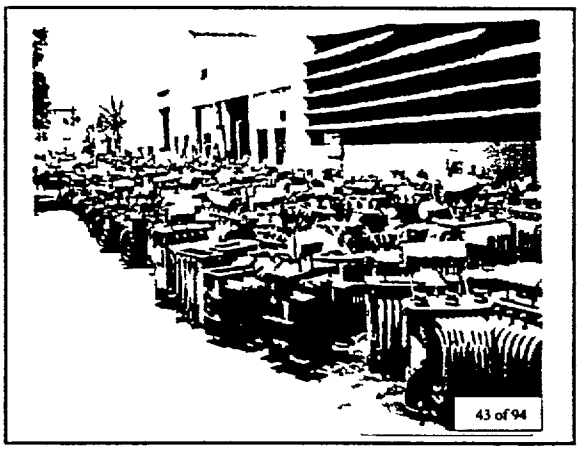

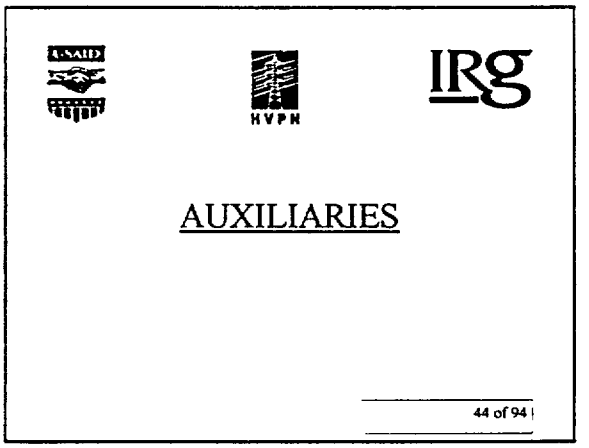

STATION BATTERIES

STATION BATTERIES SUPPLY ENERGY TO OPERATE PROTECTION EQUIPMENT SUCH AS BREAKERS AND OTHER CONTROL, ALARM AND INDICATING EQUIPMENT

THE STATION BATTERIES ARE A SOURCE TO OPERATE DC CONTROL SYSTEMS EQUIPMENT DURING SYSTEM DISTURBANCES AND OUTAGES

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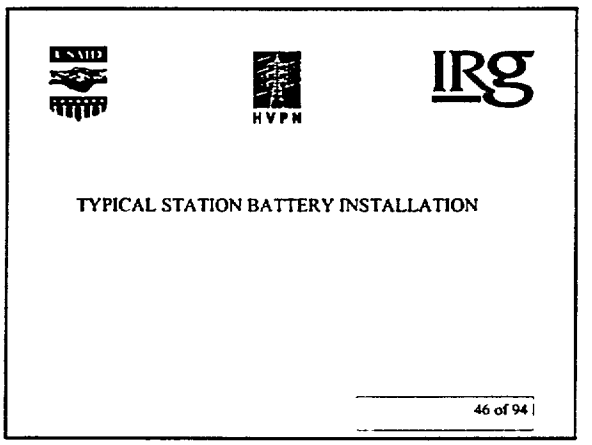

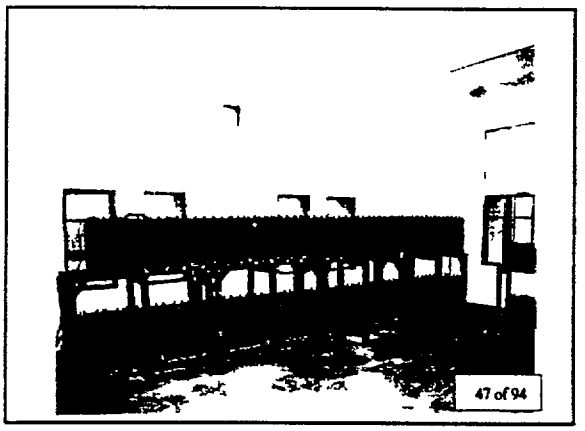

RELAY & CONTROL PANELS

PURPOSE

CONTROL PANELS INSTALLED WITHIN THE CONTROL BUILDING OF A SWITCHYARD PROVIDE MOUNTING FOR MIMIC BUS RELAYS METERS INDICATING INSTRUMENTS INDICATING LIGHTS CONTROL SWITCHES TEST SWITCHES AND OTHER CONTROL DEVICES

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USAID HVPN IRG

CAPACITORS

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CAPACITORS

CAPACITORS PROPERLY LOCATED ON THE POWER SYSTEM PROVIDE SIGNIFICANT ECONOMIC AND TECHNICAL BENEFITS TO SEB

THEY RELEASE
- GENERATION CAPACITY
- TRANSMISSION CAPACITY
- DISTRIBUTION CAPACITY

REDUCE ENERGY LOSSES

REDUCE VOLTAGE DROPS AND THEREFORE IMPROVE VOLTAGE REGULATION

INCREASE REVENUES

DEFER CAPITAL INVESTMENTS

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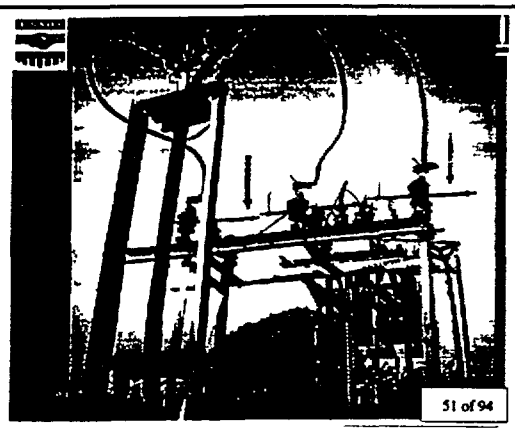

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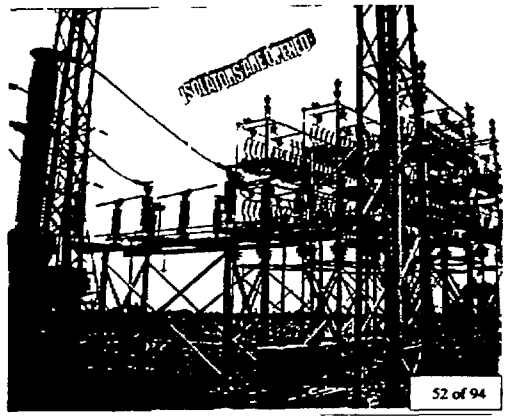

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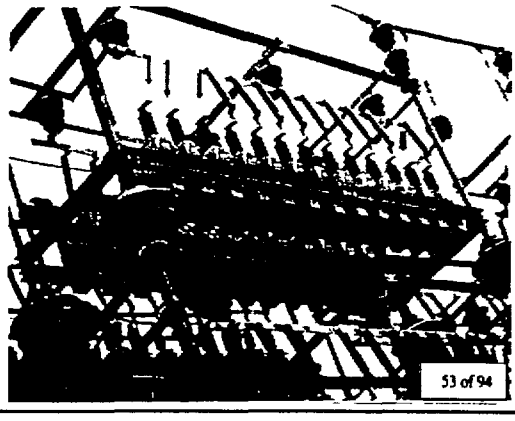

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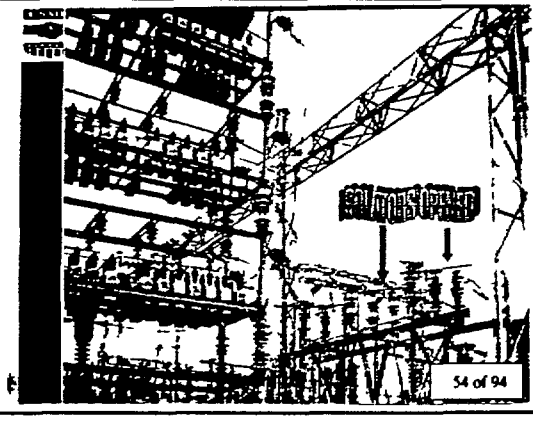

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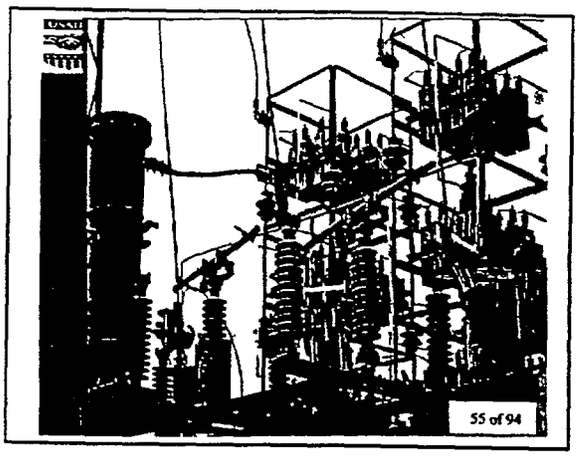
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ISOLATORS ARE OPENED
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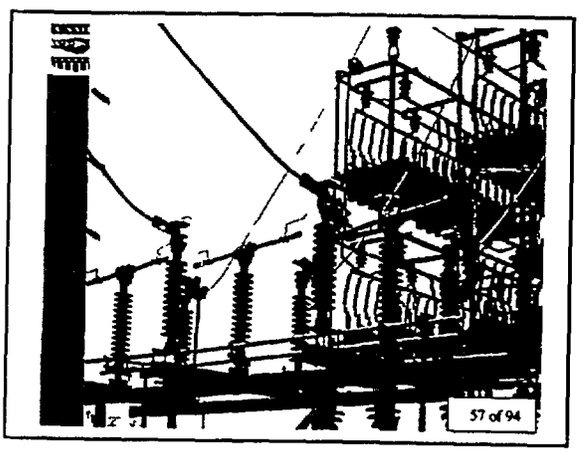
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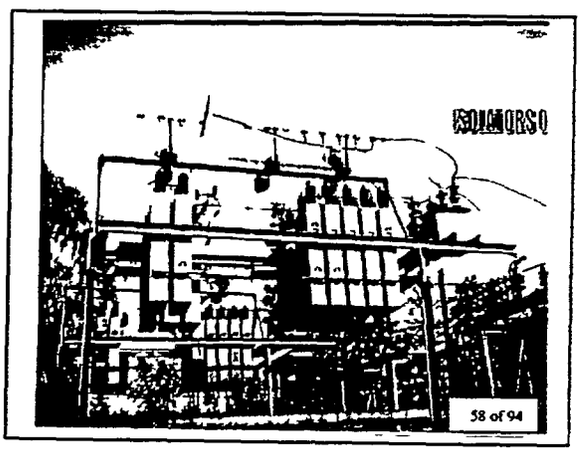
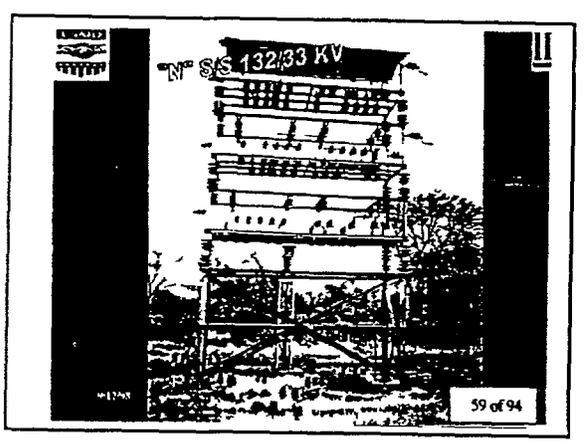
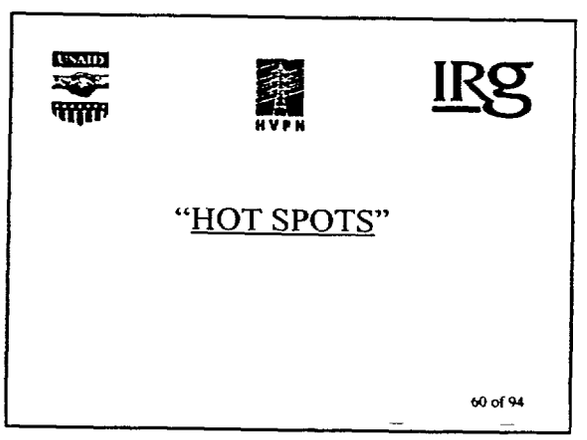
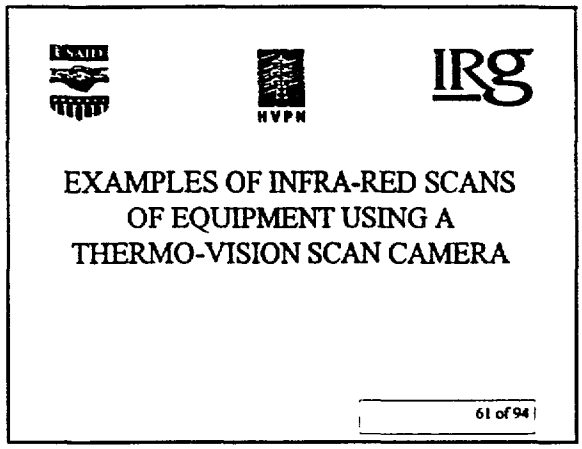
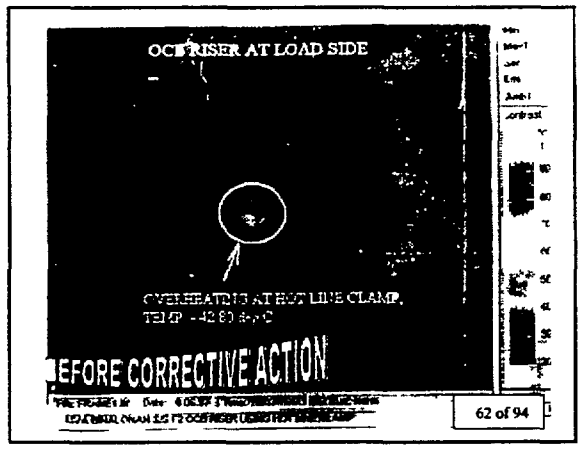
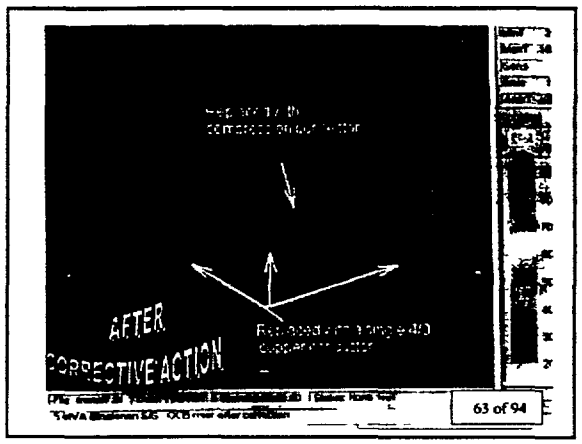

ISOLATORS
58 of 94

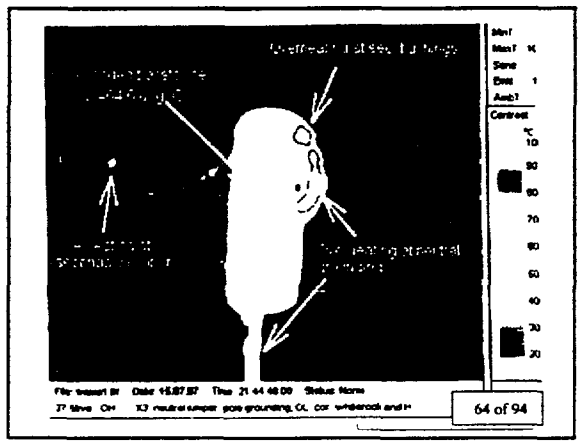

"N" S/S 132/33 KV
59 of 94

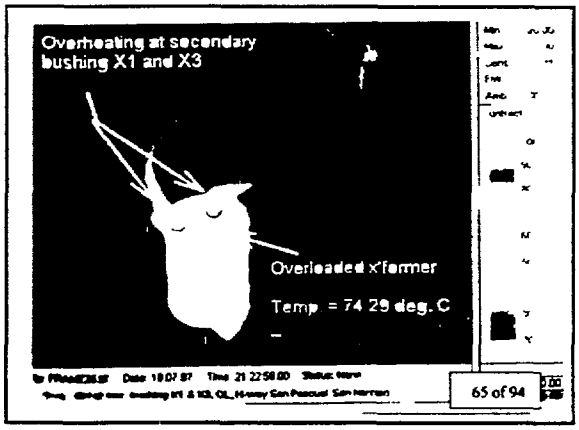

HVPN
IRg
"HOT SPOTS"
60 of 94

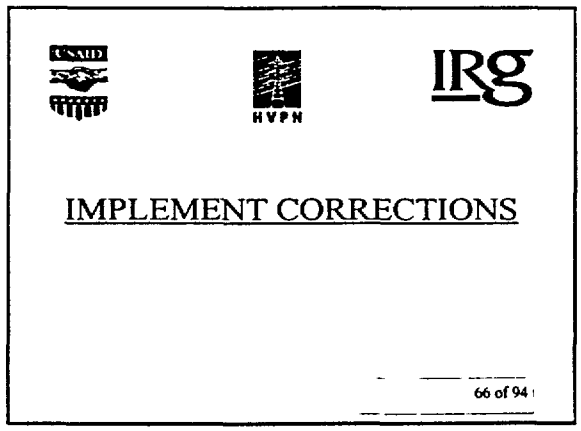

USAID
HVPN
IRg
EXAMPLES OF INFRA-RED SCANS
OF EQUIPMENT USING A
THERMO-VISION SCAN CAMERA
61 of 94


OCB RISER AT LOAD SIDE
EFORE CORRECTIVE ACTION
62 of 94


AFTER
CORRECTIVE ACTION
63 of 94


64 of 94


Overheating at secondary
bushing X1 and X3
Overloaded x'former
Temp = 74.29 deg. C
65 of 94


USAID
HVPN
IRg
IMPLEMENT CORRECTIONS
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70

HOW TO LIMIT CATASTROPHIC FAILURES REDUCE SYSTEM OUTAGES AND IMPROVE EFFICIENCY OF SUPPLY

PLAN AHEAD

PERIODICALLY MONITOR PERFORMANCE AND OPERATION OF ALL EQUIPMENT

ESTABLISH & IMPLEMENT PREVENTATIVE MAINTENANCE PROGRAMS

HAVE ACCESS TO & ASSURE AVAILABLITY OF SPARE PARTS

CONTINUED 68 of 94

CONTINUATION

HOW TO LIMIT CATASTROPHIC FAILURES REDUCE SYSTEM OUTAGES AND IMPROVE EFFICIENCY OF SUPPLY

HAVE ACCESS TO & ASSURE AVAILABILITY OF SPARE PARTS

MAINTAIN & MONITOR ALL EQUIPMENT LOGS REQUIRED BY MAINTENANCE SCHEDULES

PERFORM ALL ROUTING MAINTENANCE REQUIRED BY MANUFACTURERS OF EQUIPMENT

AS LOADS & RETICULATION OF LINES CHANGE, MONITOR THE EFFECTS ON VOLTAGE & RELOCATE OR INSTALL CAPACITORS AS NEEDED

69 of 94

PLANNING AHEAD

- PERFORM VOLTAGE SURVEYS
- PERFORM LOAD SURVEYS ON FEEDERS
- PERFORM TRANSFORMER LOAD SURVEYS
- TAKE POWER FACTOR MEASUREMENTS PERIODICALLY PARTICULARLY AT CAPACITOR LOCATIONS

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MAINTENANCE

UPKEEP OF DAILY OPERATING LOGS

UPKEEP OF PERIODIC MAINTENANCE LOGS

UPKEEP OF OUTAGE REPORTING LOGS

UPKEEP OF DEFECTIVE EQUIPMENT REPORTING LOGS

OBSERVE PROVIDED INSTRUCTIONS FOR SWITCHING CAPACITOR BANKS

OBSERVE PROVIDED INSTRUCTIONS FOR CORRECTING OUT OF TOLERANCE VOLTAGES & FREQUENCY

RIGOROUSLY CARRY OUT ROUTINE MAINTENANCE ON ALL EQUIPMENT AS REQUIRED BY THE MANUFACTURERS O&M MANUALS

71 of 94

PERIODIC MAINTENANCE LOGS

BATTERY SPECIFIC GRAVITY CHECKS

GROUND GRID RESISTANCE CHECKS

OIL LEVEL CHECKS IN TRANSFORMERS BREAKERS ETC

CHECKS ON TEMPERATURE GAUGES ON TRANSFORMERS

CHECKS ON OPERATION COUNTERS ON SURGE ARRESTERS AND CIRCUIT BREAKERS

TREE TRIMMING & FOLIAGE CONTROL CHECKS ON ALL LINES

WEED CONTROL CHECKS IN SWITCHYARD

THERMO VISION SCANS OF ALL SWITCHYARD AND DISTRIBUTION LINE EQUIPMENT

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SPARE PARTS & REPLACEMENTS

73 of 94

SUGGESTED (PARTIAL LISTING) SPARE PARTS & EQUIPMENT TO BE STOCKED

- DISTRIBUTION TRANSFORMERS OF COMMONLY USED kVA & VOLTAGE RATIOS
- AT LEAST ONE METAL-CLAD CIRCUIT BREAKER OF EACH AMPACITY RATING PER SWITCHYARD
- STATION TYPE LIGHTNING ARRESTERS
- DISTRIBUTION TYPE LIGHTNING ARRESTERS
- TRIP & CLOSE COILS FOR OUTDOOR HV BREAKERS & ALSO FOR INDOOR METAL-CLAD CIRCUIT BREAKERS.
- MV CAPACITORS
- FUSES AND FUSE CUTOUTS
- BULBS FOR INDICATING LIGHTS
- OVERCURRENT PHASE & GROUND RELAYS
- OTHER SPARE PARTS OR COMPONENTS RECOMMENDED BY EQUIPMENT MANUFACTURERS

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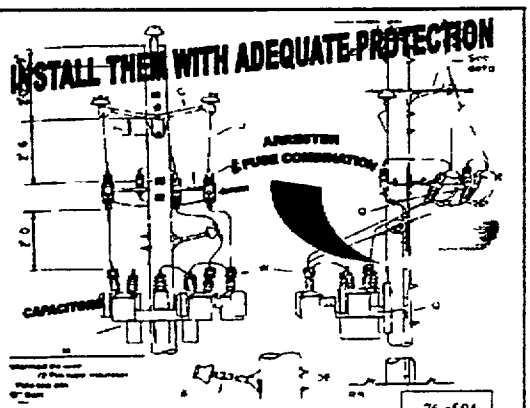
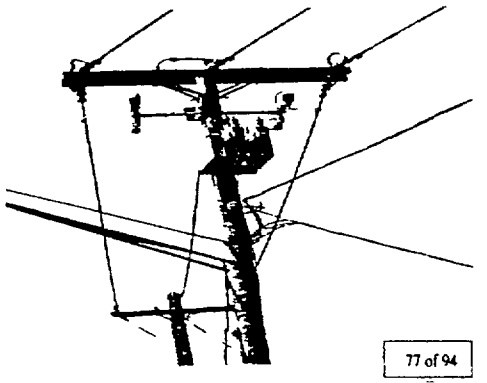
CORRECT INSTALLATIONS

75 of 94



76 of 94



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SAFE CONSTRUCTION PRACTICES

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SAFETY CLOTHING

HARD HAT
RUBBER GLOVES
EYE PROTECTION
STEEL TOE BOOTS
LINEMAN S BELT

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SAFETY EQUIPMENT

GROUNDING CHAINS
HOT STICKS
CABLE GROUNDING SPIKES
GROUND CARTS FOR METAL-CLAD SWITCHGEAR

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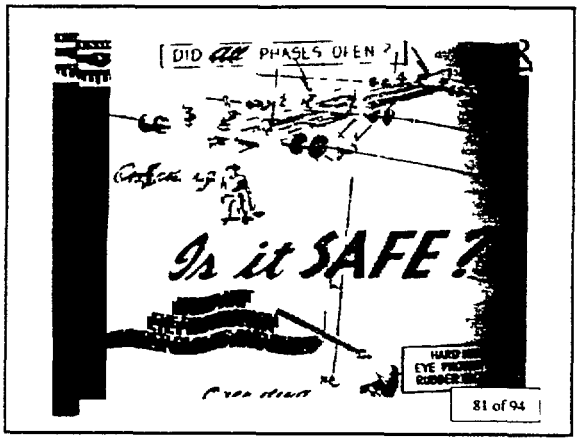

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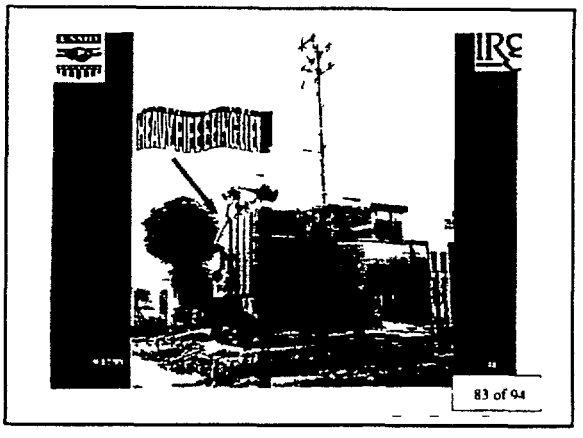
EXAMPLE OF POOR SAFETY PRACTICES

8 of 94



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EXAMPLES OF HALO AMMETER INSTALLATION

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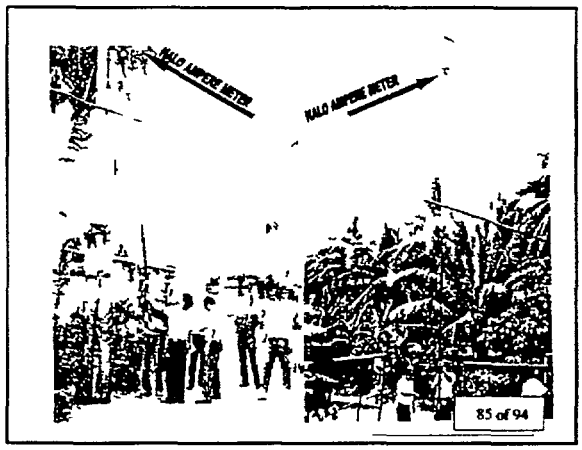

EXAMPLES OF REPLACEMENT EQUIPMENT INSTALLATION

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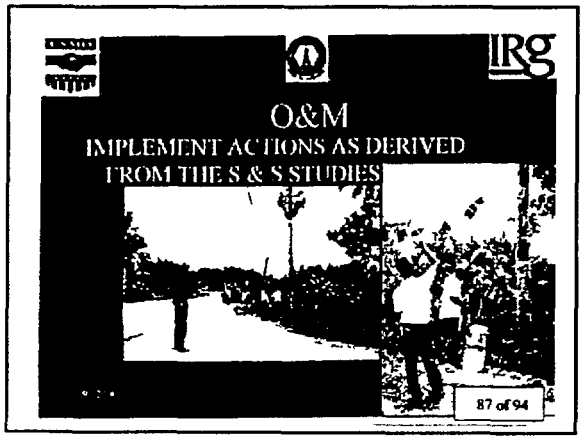

EXAMPLES OF BAD INSTALLATIONS

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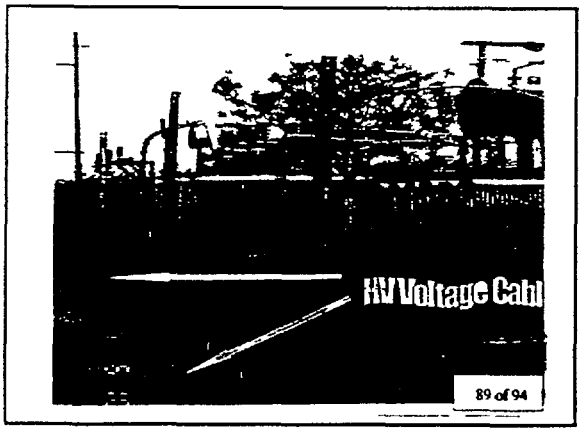
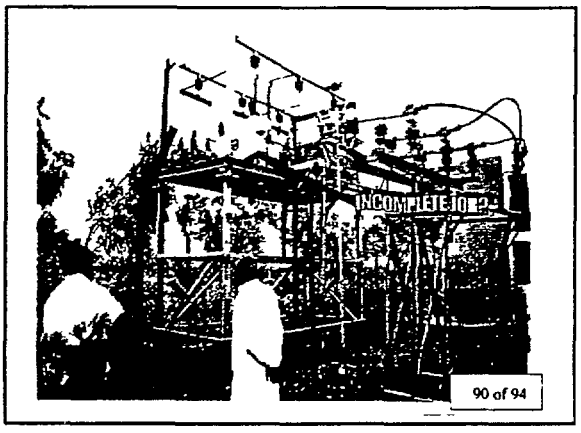
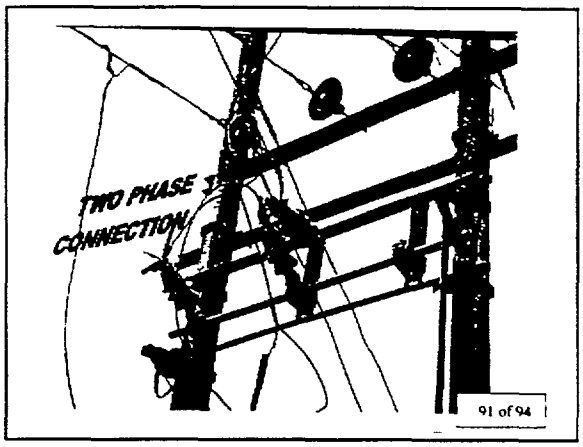
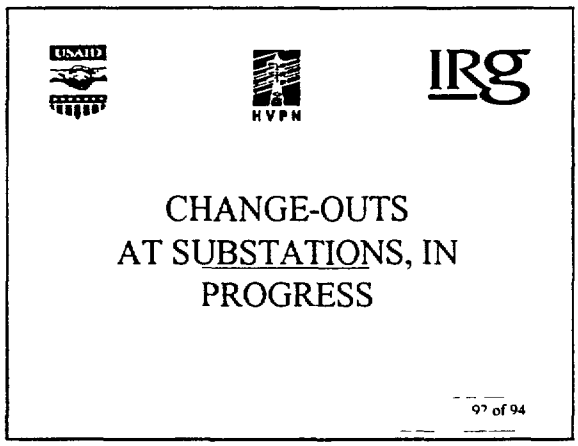





TWO PHASE
CONNECTION
91 of 94


USAID
HVPN
IRg
CHANGE-OUTS
AT SUBSTATIONS, IN
PROGRESS
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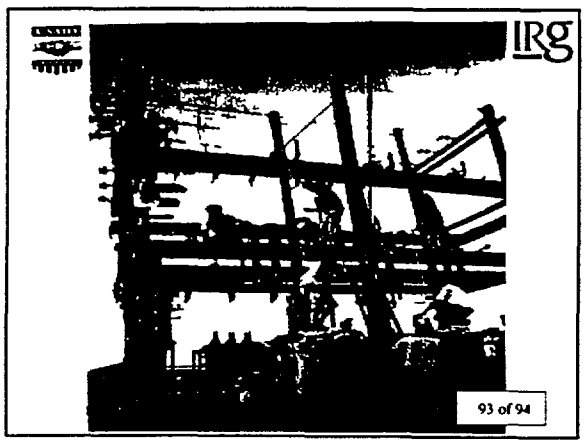
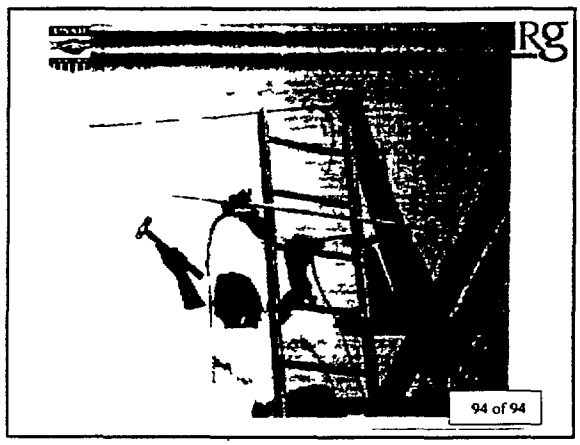

IRg
93 of 94


IRg
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APPENDIX - II

S W I T C H Y A R D S

(Lecture Notes)

IRG INTERNATIONAL RESOURCES GROUP

INDIA

SEPTEMBER 1998 – DECEMBER 1998

HVPN

IRg

SUBSTATION EFFICIENCY IMPROVEMENT TRAINING

A PROTECTION
B SYSTEM LOSSES
C OVERVOLTAGE PROTECTION
D GROUNDING

HVPN

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A PROTECTION

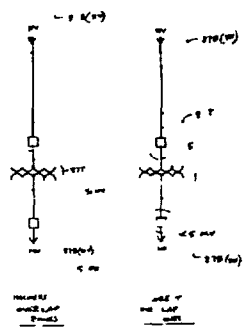
A 1 PROTECTION
A 2 RELAYING
A 3 SHORT CIRCUIT MVA & FAULT CURRENT
A 4 TRANSFORMER INRUSH & THERMAL WITHSTAND CURVES
A 5 FUSE CHARACTERISTICS
A 6 PRINCIPLES OF CO-ORDINATION
A 7 BREAKER CONTROL SCHEMATICS

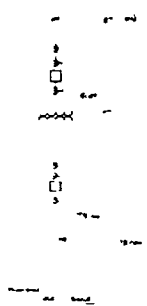
HVPN

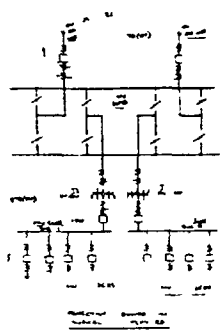
IRg

A 1 PROTECTIVE ZONES

INCORRECT & CORRECT APPLICATIONS







HVPN

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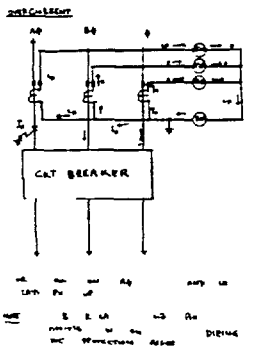
A 2 RELAYING

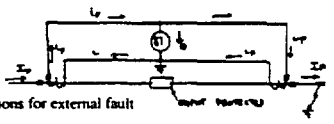
OVERCURRENT (PHASE AND GROUND FAULTS)

DIFFERENTIAL (TRANSFORMERS BUSSES)

- RESTRICTED EARTH FAULTS
- MISC XFMR RELAYING

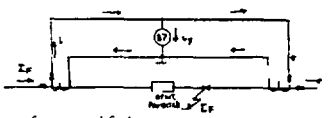


DIFFERENTIAL



Conditions for external fault

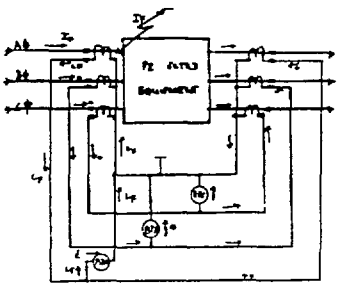
87 Relay does not operate for external faults



Conditions for external fault

87 Relay does not operate for external faults

Three phase differential connection



Therefore 87 relay on A phase sees an internal fault on the A Phase

Differential CT connection for Transformers

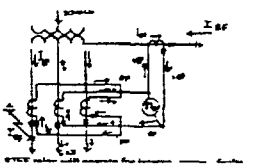
Y Y transformers must have CT s connected in D D

Y D transformers must have CT s connected in D Y

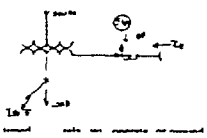
D Y transformers must have CT s connected in Y D

D D transformers must have CT s connected in Y Y

RESTRICTED EARTH FAULT



87EF relay will operate for internal ground faults



A timed 51EF relay will operate for ground faults on the system

MISCELLANEOUS TRANSFORMER RELAYING

Buchholz relay A combination of gas accumulation and pressure relay Only applicable to conservator type transformers in which the tank is completely filled with oil

SEE FIG 176
(next page)

Pressure Relief Device- Relieves minor and serious internal pressures Alarms and also trips
Sudden Pressure Device Trips out transformer for sudden pressure
Gas Detectio Relay Buchholz type
Combustible Gas Relay Samples gas
Liquid Temperature Indicators Alarms and trips
Winding Temperature (Thermal) Relays

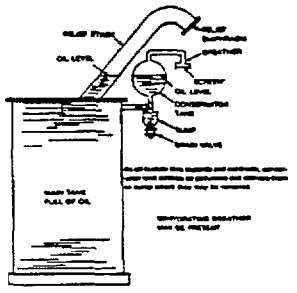


Fig 76
Conservator with System of Oil Preservation

USAID HVPN IRG

A 3 SHORT CIRCUIT MVA & FAULT CURRENT

Transformer Impedance

(Ohmic and p u values)

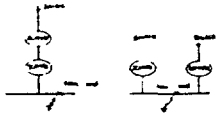
$$Z_{ohm} = Z \frac{(kV)^2}{(MVA)} \quad (1)$$

$$SCMVA = \frac{MVA}{Z} \quad (2)$$

Assume infinite bus on transformer high side.
Therefore SCMVA max 3 phase fault current on infinite secondary side. and

$$I = \frac{SCMVA}{1.73 \times kV}$$

Series nd Parallel SCMVA s



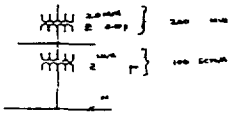
Series

$$\text{Equivalent SCMVA} = \frac{(SCMVA_1 \times SCMVA_2)}{(SCMVA_1 + SCMVA_2)}$$

Parallel

$$\text{Equivalent SCMVA} = (SCMVA1 + SCMVA2)$$

e g Series



Parallel

Equiv SCMVA = 200 100 = 300 MVA

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A 4 TRANSFORMER INRUSH & THERMAL WITHSTAND CURVES

19 x 97

Transformer Inrush Current

R le of thumb
There are two critical points on the curve
(1 1 x I for 0 1 secs
(1 25 x I_{FL} for 0 01 secs

The complete transformer inrush curve is as tabulated below

(I_{FL} Xfmr full load amps)

Time (secs)	Inrush Factor
100-300	2
10	3
1	6
0 1	12
0 01	25

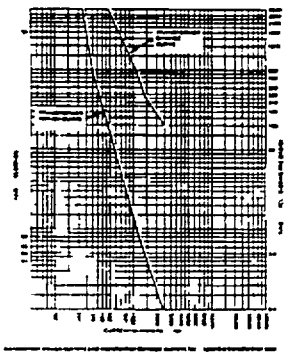
Transformer thermal damage curve - (I_{FL}=XFMR full load amps)

Time	Damage Factor
60	4 75
30	6 7
10	11 3
5	14 3
4	16 6
3	20
	25

Typical Characteristics

SEE FIG 7A3

(on next page)



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A 5 FUSE CHARACTERISTICS

Fuse Types

K fast speed (speed rati) 6–8)
T –slow speed (speed ratio 10–13)
Speed ratio = Min melt current at 0 1 secs / M n melt current at 300 or 600 secs

F se Characteristics

SEE FIG 3A3

(on next page)

(a) Fast links (K type) remove faults from system in less time & co-ordinate better w th the in verse relays
(b) Slow links ha e a greater withstand capability to trans ent and nrush currents and co-ordinate better with each other over a wide range of urrents

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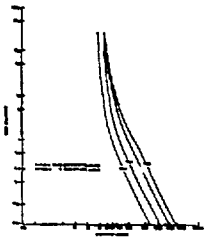

of 97

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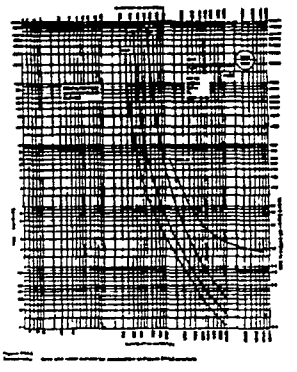
A 6 PRINCIPLES OF CO-ORDINATION

Typical Co-ordination Curves -

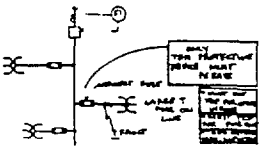
SEE FIG 25A3
(on next page)

NOTE

The difference in ordinates between curves at all values of current must be greater then 0 3 secs for good co-ordination



Selective Operation of Overcurrent Devices



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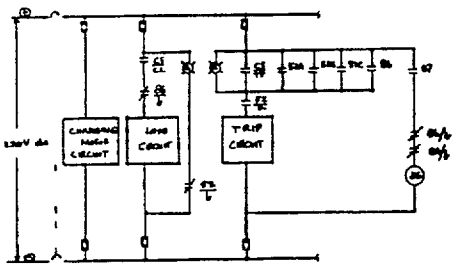
A 7 BREAKER CONTROL SCHEMATIC

BEST AVAILABLE COPY



(TYP) BREAKER CONTROL SCHEMATIC

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B SYSTEM LOSSES

B 1 PILFERAGE & METERING LOSSES

B 2 (ELECTRICAL) TECHNICAL LOSSES

B 1 PILFERAGE & METERING LOSSES

Pilferage Losses

(i) Illegal tapped connections.

(ii) Losses could be as high as 20% or more

(iii) Non metered circuits

Metering Losses

(i) Innacurate meters

(ii) Incorrectly connected meters

(iii) Incorrectly read meters

(iv) Incorrect metering constants used

B 2 TECHINICAL LOSSES

- TRANSFORMER LOSSES
- CONDUCTOR LOSSES
- CONNECTOR LOSSES

- TRANSFORMER LOSSES

(a) IRON LOSSES

These are constant for a constant applied voltage These losses can be reduced by specifying low loss transformers at time of tender Economic analysis must be performed to determine economic break even point. Lower loss transformers have higher initial costs

However higher load factors could bring in higher income and therefor ffset the "no load" losses which are present whether fmr supplies load or not.

(b) COPPER LOSSES

Thes are the I R losses Therefore fo the same load the lower resistanc will give rise to lower losses There are economic and technical trad ffs to counteract the eduction of resistance Larger conductors mean lower losses but more costly transformers

Red ced impedance means h gher SCMVA s and therefore higher interrup ing capacity switchgear downstream of the transformer

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(a) FAN AND/OR OIL PUMP LOSSES

Additional cooling of the transformer allows more MVA capacity to be loaded onto the transformer Running the fans or oil pumps for cooling adds these losses to the total losses of the transformer The efficiency of the transformer is increased if these auxiliary losses could be kept to a minimum MVA out of the transformer and still keeping within the allowable temperature rises

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CONDUCTOR LOSSES

Conductors in a substation consist of phase wires, busses, jumpers, neutral wires and ground wires Again, I^2R losses generated in conductors are caused by the current carried, and by the resistance of the conductor material Resistance is indirectly proportional to the cross section of the conductor and also dependent on the conductor material whether it be copper aluminum or ACSR Copper losses are inherent in all conductors but conductors should be optimally sized so that temperature rises when carrying maximum load current are within the prescribed standards.

(a) Jumper wires that are undersized for the loads will have higher resistances and therefore higher I^2R losses

(b) Feeders, if overloaded, carry more current than they are designed for and therefore have higher I^2R losses

(c)Normally neutral conductors in balanced 3-phase system will carry zero current Unbalances in the 3-phases will cause the unbalanced current to flow in the neutral and therefore produce I^2R losses

(d) Ground wires could also carry currents in unbalanced systems and give rise to I^2R losses

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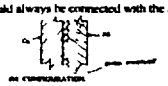
CONNECTOR LOSSES

(a) BI-METALLIC CONNECTORS

When acidic moisture penetrates the interface of two dissimilar metals "battery effects created which produces electrolytic degradation of the metals This causes a high resistance connection to develop over time

Dissimilar metals should always be connected with the appropriate bi-metal connector



(b) CONFIGURATION

Connectors should be chosen to have the proper configuration to suit the shape of the conductors being connected.

Different configurations

( ) Cable to cable — wedge connectors

(SEE TEST DATA IN NEXT PAGE)

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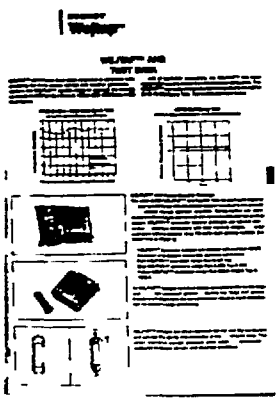

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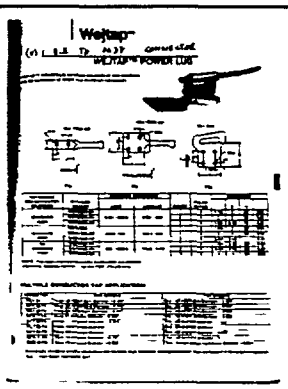

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(ii) Cable to cable — parallel groove clamps

(SEE NEXT PAGE)

(iii) Cable to stud connector

(iv) Snail clamps — strain conductor to jumper

Using incorrect configurations causes higher contact resistance and therefore higher I R Losses

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(c) SIZE

Connectors should be sized to have the same cross-sectional areas to match those of the conductors they are connecting

If incorrectly sized, higher contact resistances resulting would cause higher I^2R losses

(d) FASTENERS

Bolts used in bolted connectors must be compatible with the metals of the connector or else the electrolytic effect will corrode the bolts resulting in an ineffective fastener and thereby increasing the contact resistance between connector and conductor Wedges used in wedge type connectors must be correctly applied so that the designed clamping pressure is achieved Insufficient clamping pressure will result in increased contact resistance and therefore higher I^2R losses will occur at the connection

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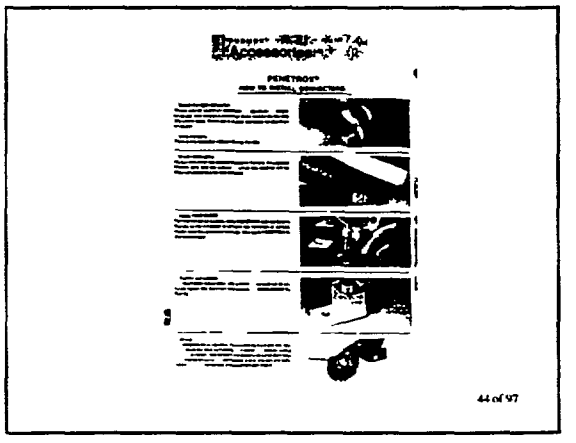

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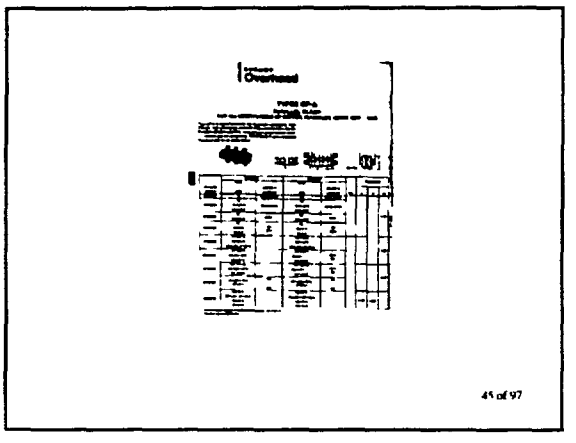

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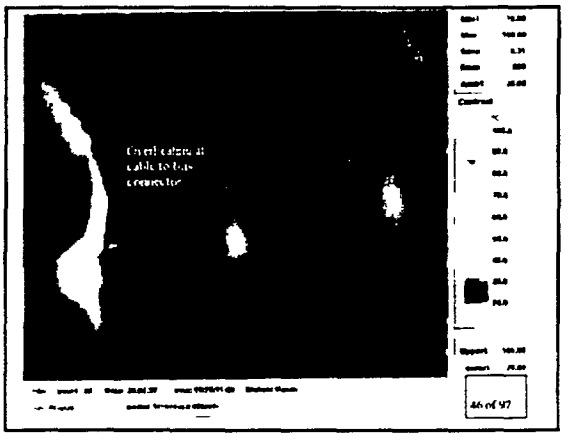

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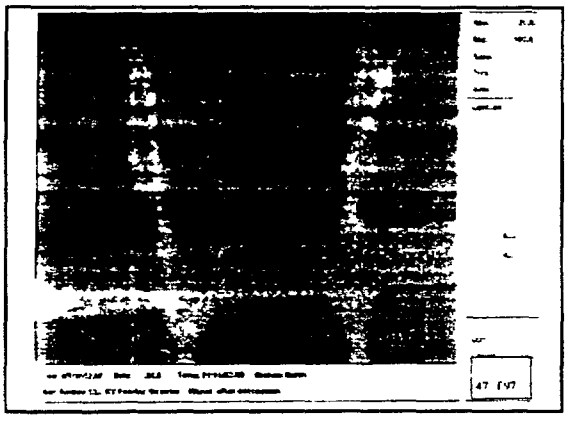

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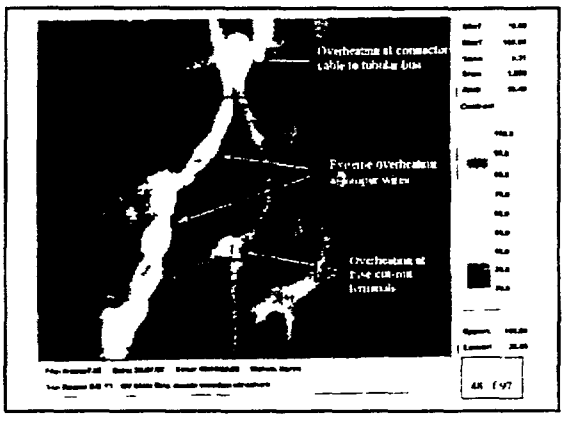

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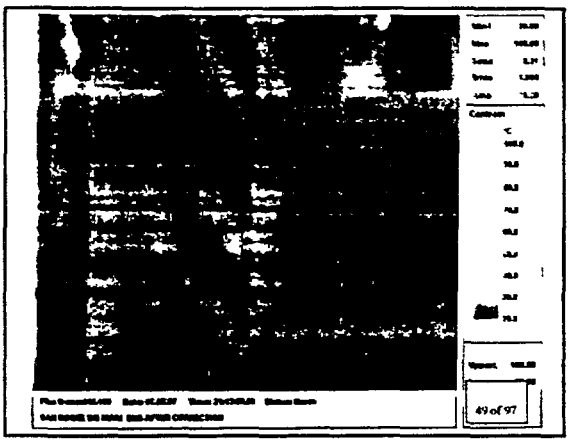

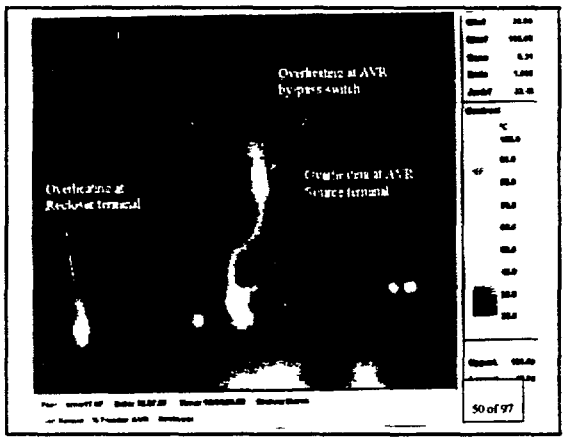

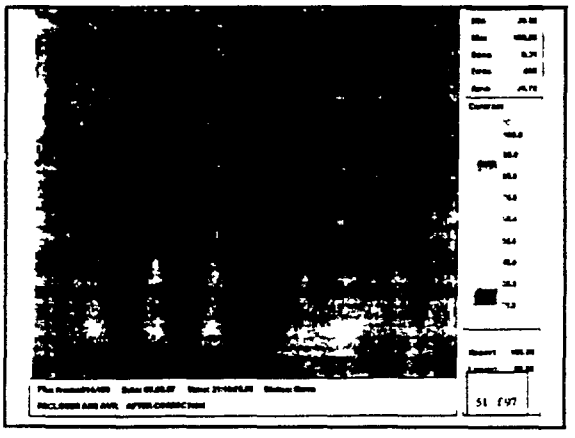

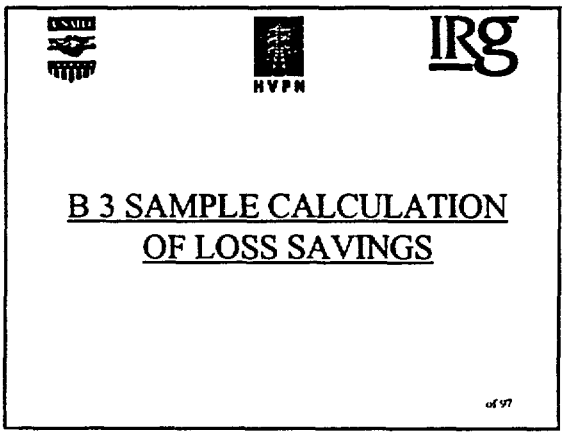

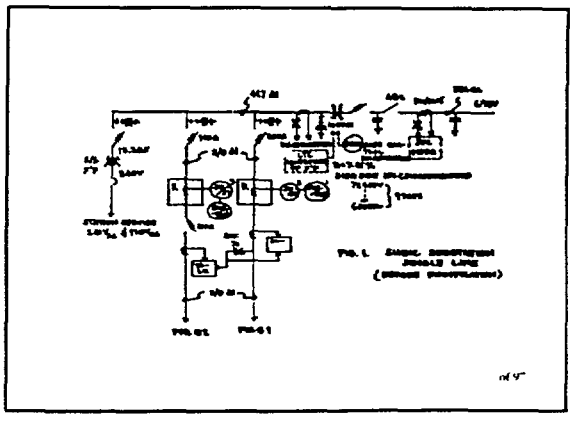

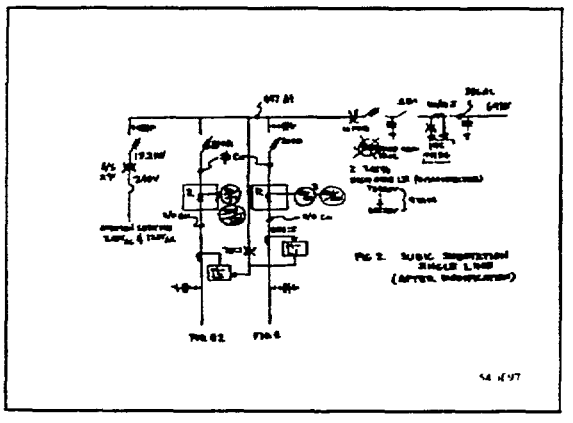

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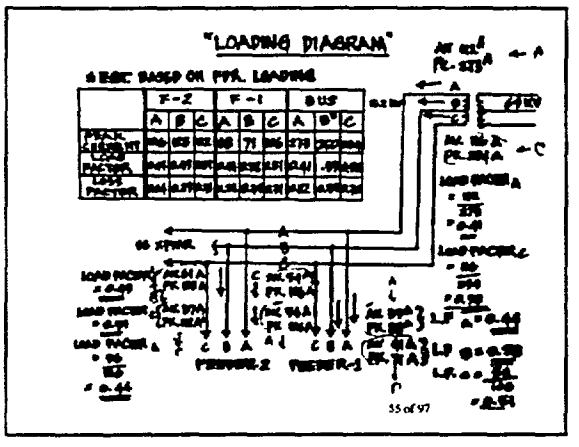

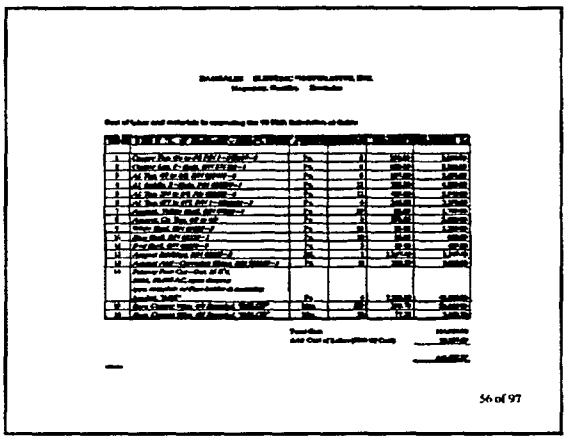

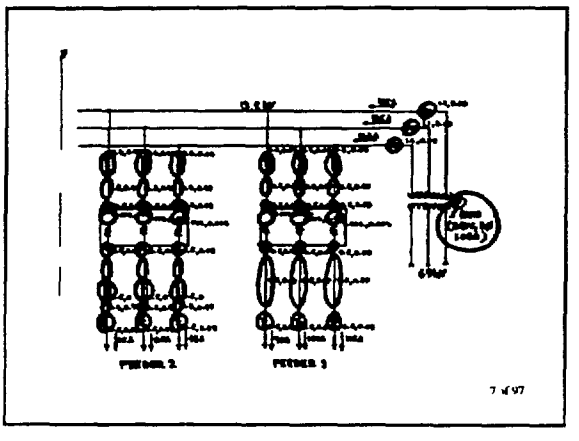

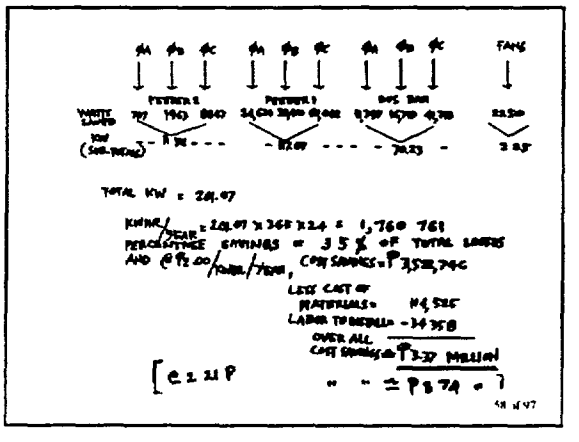

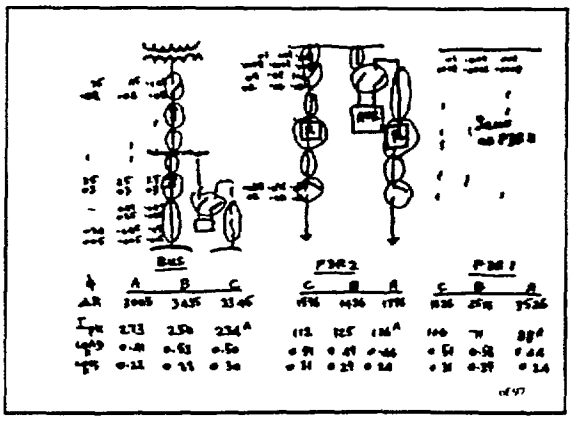

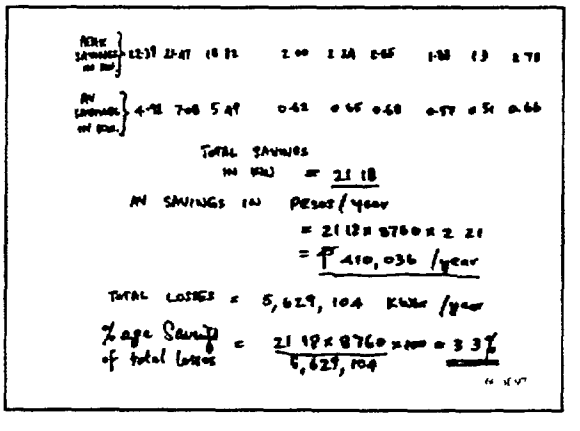

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B 4 VOLTAGE CONSIDERATIONS

CAPACITORS

AUTOMATIC VOLTAGE REGULATORS

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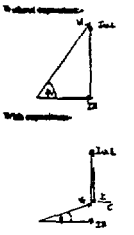
CAPACITORS



[Also, capacitors have very low I²R losses]

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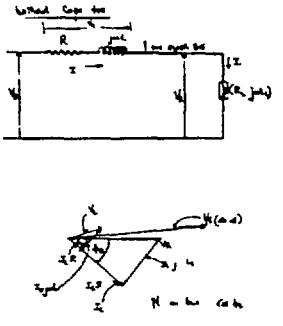

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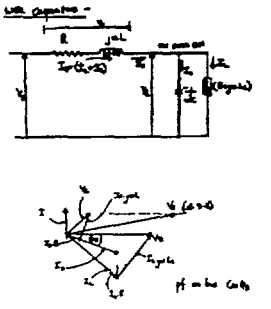

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Comparing the two above cases

Therefore With Capacitors

For the same V_R V_s is less

I e For the same V_s V_R is greater

I e Capacitors boost the voltage V_R.

Also angle ϕ_B is smaller

Therefore Cos ϕ_B is larger and closer to unity

I e Capacitors improve the power factor and adjust it closer to unity for a lagging load.

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AUTOMATIC VOLTAGE REGULATORS

Automatic voltage regulators keep the voltage near nominal voltage when increased current loads in line resistances cause bigger voltage drops (i e IZ drops) These larger loads therefore deliver reduced voltages for the receiving ends of the line

For say constant kVA loads when voltage goes down the current goes up and therefore the I R losses on line increase

AVR s maintain the voltage at nominal preset values for varying load currents AVR s themselves however have winding copper losses and iron losses

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C OVERVOLTAGE PROTECTION

C 1 LIGHTNING ARRESTERS

C 2 APPLICATION OF LIGHTNING ARRESTERS IN SYSTEM

C 3 INSTALLATION OF LIGHTNING ARRESTERS IN STSTEM

C 4 LIGHTNING SHIELD WIRES

C 5 ROD GAPS

C 6 ARRESTER GROUNDING

C 7 APPLICATION TO CAPACITOR BANKS

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OVERVOLTAGE PROTECTION

General

Overvoltages are caused by lightning, or switching surges. Lightning gives rise to high voltage transients. Equipment is therefore designed for higher than normal voltage withstand called "BIL" or "Basic Insulation Voltage Level"

BIL however may not be high enough to withstand voltages as high as those associated with transient overvoltages

C 1 LIGHTNING ARRESTERS

Types

(a) Distribution

1 30 kV They have the highest discharge voltage No requirements for pressure relief

(b) Intermediate

3–15 kV Better protection characteristics than Distribution class. Limited pressure relief requirements

(c) Station

3–684 kV Lowest discharge voltage (I allows lowest discharge voltage to appear across equipment) Good pressure relief capability

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Silicon carbide (SiC) material used in arresters is being superseded by metal-oxide varistors (MOV) MOV have greater efficiency and improved margins of protection. MOV arresters are made up fr metal oxide discs which are highly non linear No series gap is used because discs permit only low leakage currents at operating voltages, and also interrupt power follow current when voltage endures to system nominal voltage

2 APPLICATION OF LA IN SYSTEM

MCOV Max continuous operating voltage

$$V_{max} = \frac{V_L}{1.732} \times 1.05$$

Where 1.05 is a typical max cont. voltage operating factor

System kV		Arrester Rating kV					
Nom	Max	MOV				Series Gap E	
		90	MOV	90	90	90	MOV
47	47						
110	123						
69	72			90			
46	48		84				
34	36	90	90				
23	24	60	60				
14.4	15	72	72	60	60		
	7.2			30			
				60			

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The parameters for insulation co-ordination design are selected by the utility

Majority of arresters used on distribution systems are distribution class Distribution arresters are used on 1-ph or 3-ph transformers below 1500 kVA, typically

However where arresters are to be located on riser poles to protect cable connected equipment, or in substations to protect larger equipment, intermediate or even station class arresters must be used

C 3 INSTALLATION OF LA'S IN SYSTEM

Short leads to protected equipment

Arrester and protected equipment must have common interconnecting metallic ground

•On overhead lines with no shield wires, LA s should be placed in all 3 phases every 1200 ft and greater than 300kV BIL (with distribution transformers along lines and LA s on their HV side this is automatically accomplished)

At overhead line to cable interface

At overhead line to transformer interface

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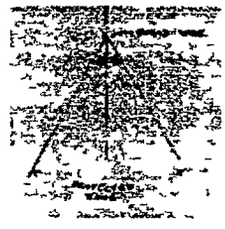
C 4 LIGHTNING SHIELD WIRES

Shield wires intercept most direct lightning strokes. Protective coverage afforded is 30 degrees with the vertical



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C 5 ROD GAPS

	kV Neg Impulse F O	
Gap Spacing (ins)	Air Gap	Rod Gap
12	250	260
18	365	360
24	480	480
30	600	575
36	660	675

Rod gaps

Advantages

Cheaper than arrestors

Disadvantages

Protection quality poor

Difficult to set correct gap spacing especially here used with circuit breakers and transformer mounted gapping arrestors gaps must flash over here breaker is open

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C 6 ARRESTER GROUNDING

Incorrect

SEE FIG 13B3

(on page after next)

High discharge current flowing through impedance causes high voltage to be impressed on primary winding Therefore high voltage is impressed on primary winding to secondary winding and between primary winding and tank.

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Correct

SEE FIG 14B3

(on next page)

Connection to a common ground point at the secondary neutral (and tank) reduces stress to a small impedance drop inherent in the arrester

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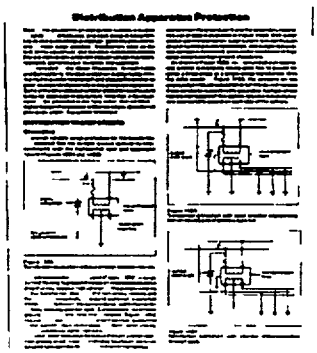

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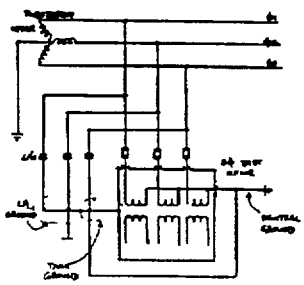
Arrester application on a grounded wye transformer



Note

All grounds are interconnected.

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C 7 APPLICATION TO CAPACITOR BANKS

Surge arresters should be used at capacitor banks regardless of size

For substation banks use station class arresters

For line banks mounted on poles distribution class arresters are adequate

To minimize spurious fuse blowing apply arresters to source side of capacitor fuses and capacitor switches

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D GROUNDING

D 1 HV SWITCHYARD GROUNDING

D 2 GROUNDING OF SWITCHGEAR IN CONTROL BUILDING

D 3 DISTRIBUTION SUBSTATION GROUNDING

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D GROUNDING

General

Basic purpose of grounding is to

Limit shock voltages for personal safety

Prevent equipment damage

Personal safety is achieved by limiting shock voltage on normally non-current carrying metal parts of equipment.

Equipment damage is prevented by providing a low impedance fault current return path needed for fast operation of the circuits protective devices

D 1 HV SWITCHYARD GROUNDING

(a) Step and Touch Potentials

(i) *Improperly grounded equipment*

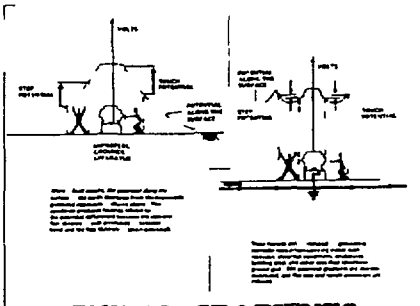
SEE NEXT TWO PAGES

When fault occurs, potential along the surface of earth decreases as shown Step and touch potentials are high

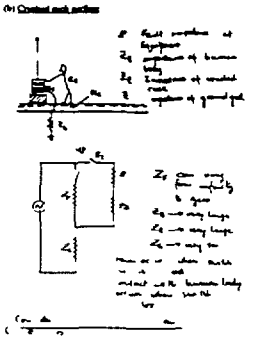
(ii) Properly grounded equipment

SEE NEXT PAGES

The grid reduces potential gradients and thereby step and touch potentials are greatly reduced



POTENTIAL GRADIENTS



The fault current is only limited by Z_1 and is therefore large and operates the protective equipment to de-energize the circuit Theoretically no current will flow through the human body impedance Z_H

(b) If Z_1 is small

$$\text{Current through the human body} = \frac{Z_1 \times I}{Z_1 + Z_2 + Z_3}$$

small

By increasing Z_H the current could be reduced even further

(c) If Z_1 is large

$$\text{Current through the human body} = \frac{Z_1 \times I}{Z_1 + Z_2 + Z_3}$$

By ensuring that Z_H is very very large the value of current through the human body can be reduced to acceptable limits

Therefore it is mandatory that the designed value of Z_H is maintained throughout the operating life of the switchyard

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D 2 GROUNDING OF SWITCHGEAR IN CONTROL BUILDING

(a) Equipment Grounds

(b) Ground fault return conductor

(a) EQUIPMENT GROUNDS

•Ground all raceways

•Ground switchgear control cabinets, AC distribution panels, and DC distribution panels.

•Ground all cable trays, conduits, and raceways.

•Ground building steel.

•Ground power cable armoring.

All of the above to be grounded and bonded to the switchyard ground grid.

(b) GROUND FAULT RETURN CONDUCTOR

During ground fault, the ground fault return conductor must provide a low impedance path to the fault current to return from ground fault anywhere in the system to the source of power. This is necessary for the fast operation of the protective device. It is therefore essential that the ground fault conductor be continuous from the source of power through the raceways and down to the load.

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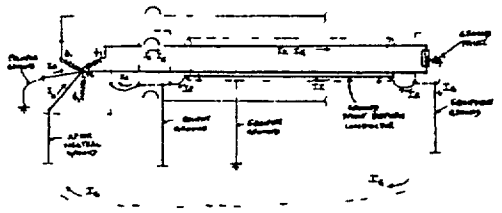

GROUND FAULT RETURN PATHS

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If no metallic ground return path, $Z_n \rightarrow \infty$ (infinity)

Therefore $I_n \rightarrow 0$

Z_1 is high depending on the equipment grounds and interconnections

Therefore I_1 is small

Fault current to trip breaker I_n I_1 = small current

Therefore breaker may not trip

If there is a direct metallic ground return path,

$Z_n \rightarrow 0$

Therefore I_n →very large

Therefore fault current to trip breaker = $I_n + I_1$ =Very large

Install continuous ground wire in all power trays, power conduits, and power raceways

Ensure that all electrical equipment has continuous metal path from source to the load.

DON T use ground fault return conductor as a source for equipment ground.

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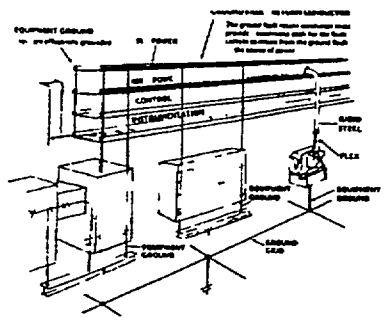

TYPICAL

GROUNDING SYSTEM

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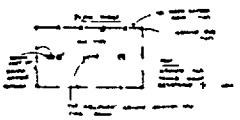
D 3 DISTRIBUTION SUBSTATION GROUNDING



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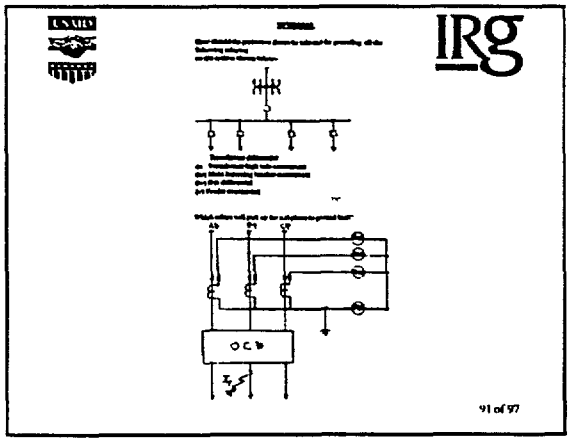

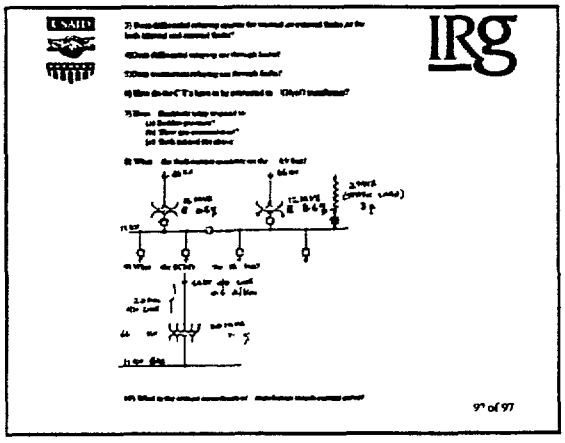

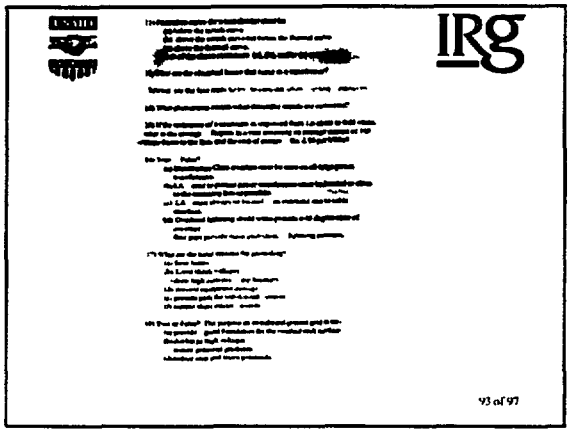

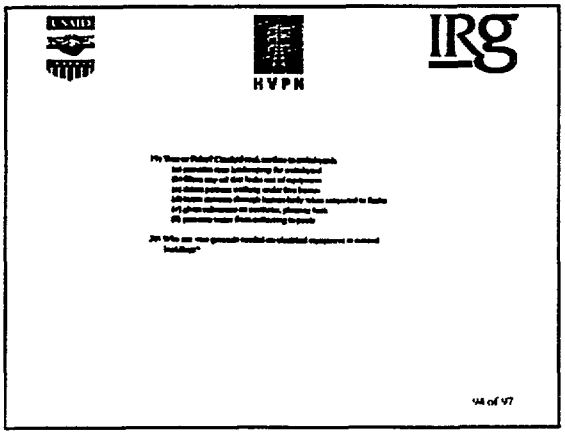

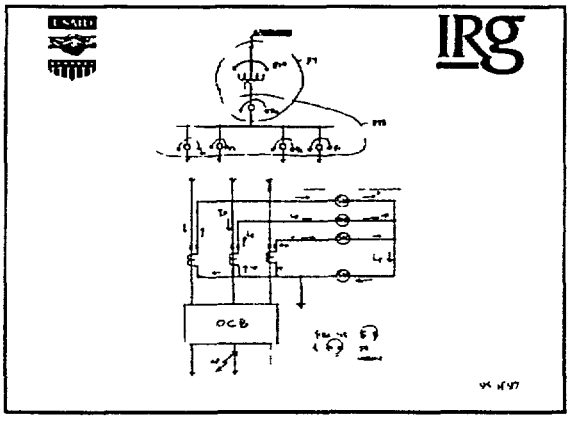

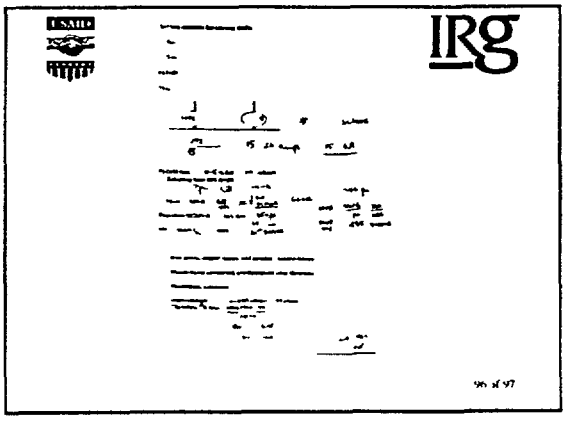

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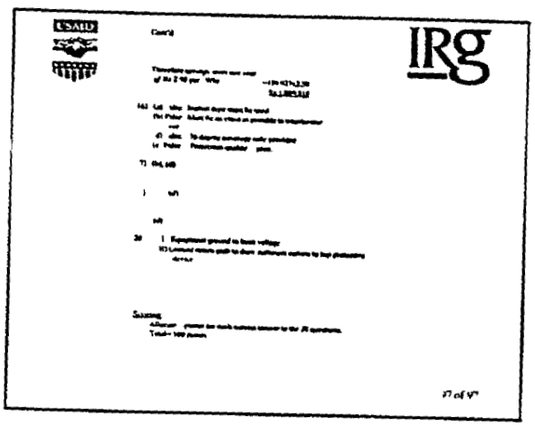

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APPENDIX - III

DISTRIBUTION SYSTEM PLANNING

(Lecture Notes)

IRG INTERNATIONAL RESOURCES GROUP

INDIA

SEPTEMBER 1998 – DECEMBER 1998

System Efficiency Improvement Project

Training Manual

Computer Modeling of Distribution Feeders

For

Distribution System Planning and Design

Prepared by

International Resources Group

Working Under Contract to the

United States Agency for International Development

For

Haryana Vidyut Prasaran Nigam Limited

Formerly known as

Haryana State Electricity Board

HVPNL - SYSTEM EFFICIENCY IMPROVEMENT TRAINING PROJECT

October 23, 1998

Training Session Participants,
Haryana Vidyut Prasaran Nigam Limited
Haryana State, India

Dear all participants

We would like to welcome you to this training session designed to provide training in the area of computer modeling of distribution feeders

This manual is intended to be the primary aid in the training class It is our hope that it will be of use during the training session and in your work afterwards

With the advent of affordable computers and software, electric utility distribution engineers now have the opportunity to develop more accurate and detailed models of their systems This can result in more detailed planning studies and a more efficient system This is essential in an environment where costs must come down and service to customers must improve

Thank you for your participation and good luck in your continuous efforts for the people and electric customers of Haryana

Sincerely,

System Efficiency Improvement Training Team
International Resources Group
United States Agency for International Development

HVPNL - SYSTEM EFFICIENCY IMPROVEMENT TRAINING PROJECT

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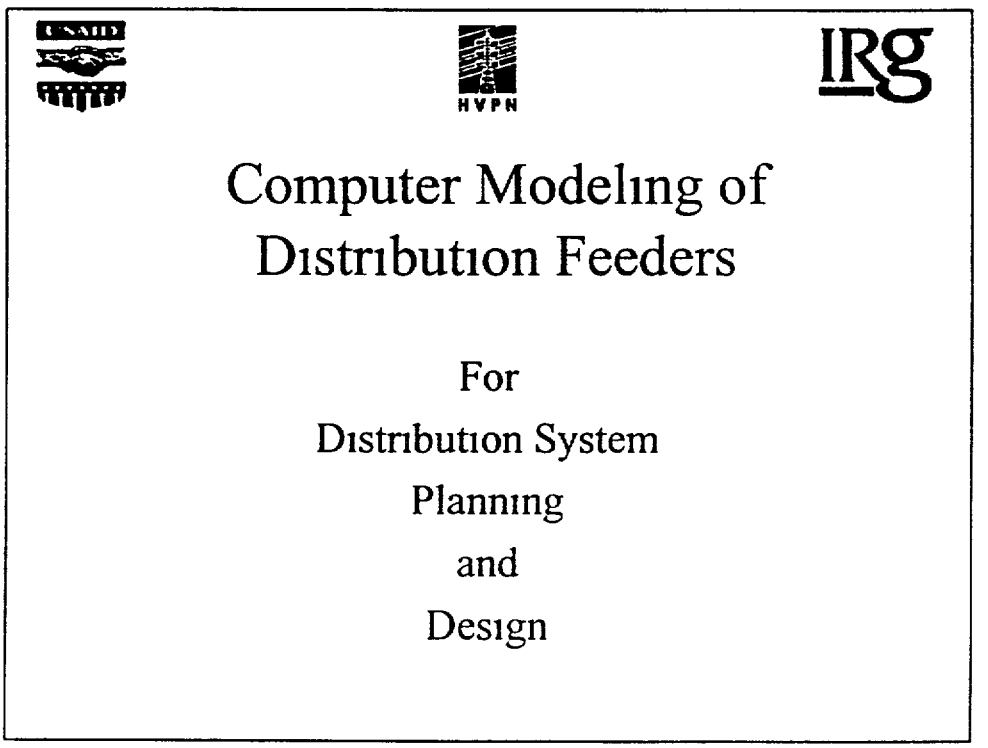
V Workshop Modeling Local Feeders

Materials Needed Feeder HT diagrams, transformer data, load data, LT diagrams

I Overview Presentation

This part of the text can be used as part of this training program or used separately The purpose is to give engineers and other utility personnel an overview of why and how computer modeling of distribution feeders is done as well as an opportunity to ask questions on the topic



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Purpose for Doing Computer Modeling

Facilitates and improves quality of

- Distribution System Planning
- Short Circuit Studies
- Relay Coordination
- Load Flow analysis

What is needed?

- Distribution System Data
- Hardware IBM-PC Compatible
- Software Loadflow analysis software
  - Stoner PTI PSS/U
  - PTI PSS/U
  - Cooper Power Systems
  - ABB
  - Stoner
  - Milsoft

Distribution System Data Needed

- Distribution Feeder HT Lines Conductor Sizes and Distances
- Distribution Transformer Data
- Load Data KVA, KW,KVAr, PF
- Source Data

Collection of Data

Obtain or Draw Geographical Diagram of Distribution Feeder showing distances of all lines and all connected load

CREATE DRAWING

Create drawing using the analysis software that accurately represents the distribution feeder

Geography should be reasonably accurate

Important customers or loads can be included

Important junctions should be shown

A node should be chosen at any wire size change

Small details can be excluded

Interconnected Sections

The distribution feeder model consists of interconnected sections, the characteristics of which will be specified by the engineer

Modeling Loads

Group loads together when many small loads are close together

Spot loads can be place at the source end or load of a section

Distributed loads are distributed along the length of a section

Run Load Flow of Base Case

- To confirm that the data that was entered gives output similar to real life situations
- To calculate electrical characteristics such as voltages, currents, load flows and losses of present system

Modify System and Run Load Flow to Compare Results

- Problems with existing system often suggest several solutions
- Changes can be made in the computer model to compare performance of each solution
- Confirm that changes do in fact solve present or future problems

Summary of Feeder Modeling Process

- Collect Data
- Draw Feeder
- Model Loads
- Run Load Flow of Base Case
- Modify System and Run New Model

II Review of Line Losses and Reactive Compensation

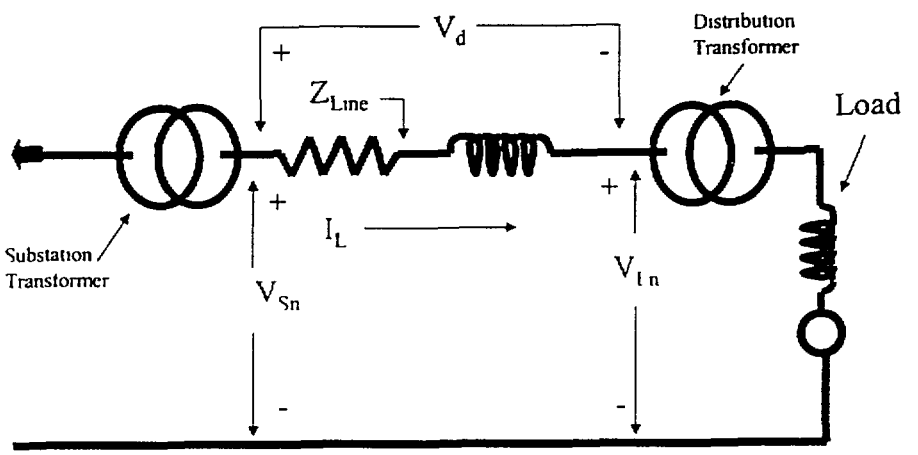
In order to review the benefits of compensation for reactive loads, i e installing capacitors to offset inductive loads, we will study a very simple case showing a highly inductive load fed by a single distribution line from a single source

In this example the source and load are Y connected with a zero impedance earth return

For simplicity sake, we will consider this a single phase line and a single phase load The same ideas will hold true for three phase lines and more complicated distribution circuits

Simplified Diagram of a Distribution Feeder

Single Source - Single Line - Single Load



Consider the following values for the calculations

V_{Sn}	Line to Neutral Voltage at Source (Volts)
V_{Ln}	Line to Neutral Voltage at Load (6350 Volts)
Z_{Line}	Impedance of Line 6 + j 3 5 Ohms
V_d	Voltage Drop from Source to Load (Volts)
I_L	Line Current in Amps
$S_{L1\phi}$	Single Phase Complex Power Delivered to Load 500 kVA at 8 power factor, lagging

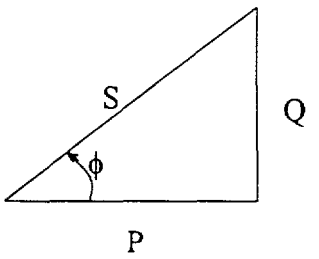
A voltage loop equation can be established for our circuit

$$V_{Sn} = V_d + V_{Ln}$$

Where $V_d = I_L Z_{Line}$

$$V_{Sn} = I_L Z_{Line} + V_{Ln}$$

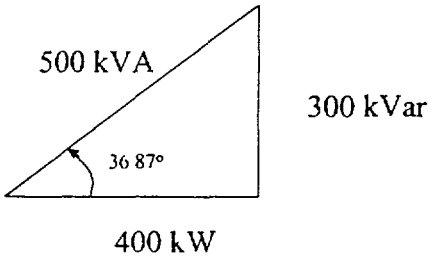
The power triangle represents graphically the equation
$S = P + jQ$, where S is the complex power,
P is the real power and
Q is the reactive power
in a particular circuit



In the given case the load is such that

500 kVA = 400 kW + j 300 kVar

and can be represented with the following power triangle



Providing rated voltage of 6350 volts at the load, the current drawn is

$$I_L^* = \frac{S_{1\Phi}}{V_{Load}},$$

Where I_L^* is the complex conjugate of I_L

$$I_L^* = \frac{400\,kw + 300\,kVAr}{6\,350\,KV\lfloor 0° \rfloor},$$

Using V_{load} as the reference Bus

$$I_L^* = 63\,0 + j47\,2\,Amps$$

$$so\,that \quad I_L = 63\,0 - j47.2\,Amps$$

$$I_L = 63\,0 - j47\,2\,Amps\,or$$
$$78\,74\lfloor -36\,87° \rfloor Amps$$

The real power losses in the line,
P_L are

$$P_L = |I_L|^2 R,$$

Where R is the resistance of the line given in Z_{Line}

So,

$$P_L = (78\,74\,Amps)^2 (6\,Ohms)\,or$$
$$37\,2\,kW$$

The percent power loss is

$$\frac{37\ 2}{37\ 2+400}\ or\ 8\ 5\%$$

Of the total real power supplied by the source

Voltage Drop

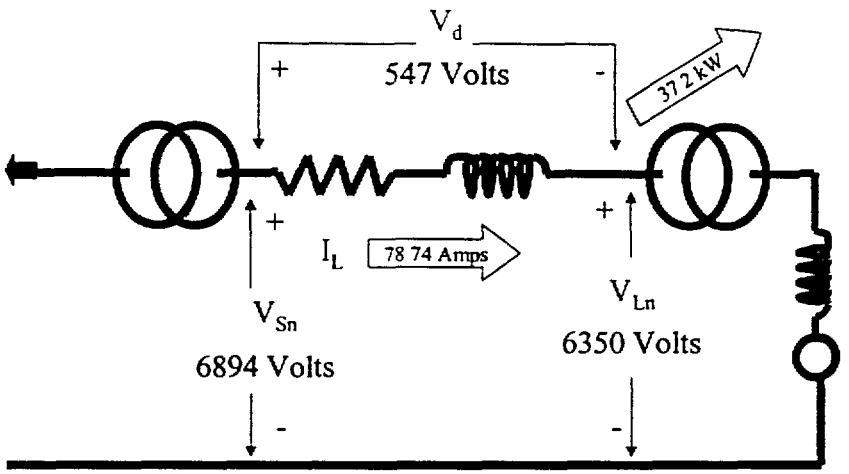
$$V_d = (78\ 74 Amps\lfloor -36\ 87° \rfloor)(6\ 95 Ohms\lfloor 30\ 26° \rfloor)$$
$$V_d = 547 Volts\lfloor -6\ 61° \rfloor$$
$$|V_d| = 547\ volts\ or$$

8 6% Of the 6350 volts needed at the load

The voltage needed to maintain rated voltage at the load is

$$V_n = V_d + V_{Ln}$$
$$V_n = 547\ v\lfloor -6\ 61° \rfloor + 6350\ v\lfloor 0° \rfloor$$
$$V_n = 543\ 36\ v - j62\ 97\ v + 6350\ v$$
$$V\ = 6893\ 36\ v - j62\ 97\ v$$
$$V\ = 6893\ 65\ v\lfloor -52° \rfloor$$
$$|V_n| = 6893\ 65\ volts$$

Load Flow of Sample Feeder - Base Case



Let us examine the effect of placing a capacitor at the load

Since 300 kVar are absorbed by the load, lets use a 300 kVAR capacitor

The total power absorbed at the load is now

$$S_{1\Phi} = 400kw + j300kVar - j300kVar$$

Real Power

Reactive Power From Inductive Load

Reactive Power "supplied" by Capacitor

$S_{1\Phi} = 400kw$ Representing a unity Power Factor

The current is now

$$I_L^* = \frac{400\,kw}{6\ 35kv\lfloor 0° \rfloor} = 63\ 0\,Amps\lfloor 0° \rfloor; \quad |I_L| = 63.0\,Amps$$

And the power losses

$$P_L = (63.0\,Amps)^2 (6\,Ohms)\,or$$
$$23\ 8\,kW$$

The savings is $\Delta P_L = 37\ 2 - 23\ 8\ or,$
$13\ 4\,kw.$

The percent power loss is now

$$\frac{23\ 8}{23\ 8 + 400}\ or\ 5\ 6\%$$

Of the total real power supplied by the source

This represents a savings of 13 4 kW or 2 9 %

Voltage drop is now

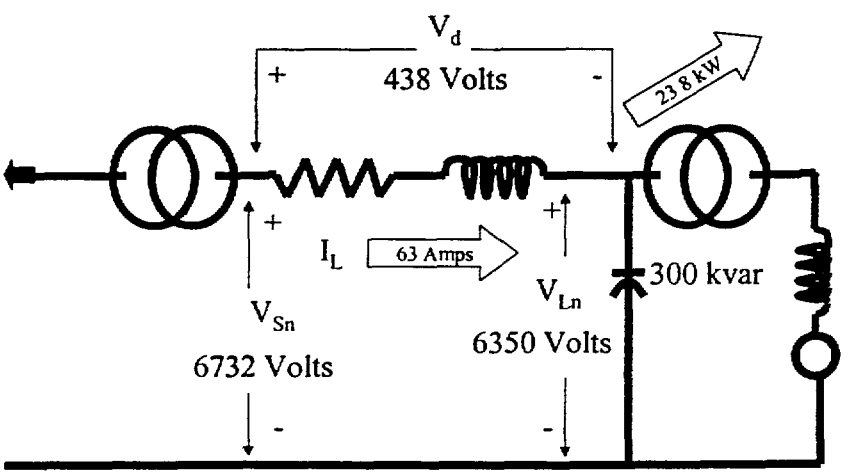
$$V_d = (63Amps\lfloor 0° \rfloor)(6\ 95Ohms\lfloor 30\ 26° \rfloor)$$
$$V_d = 437.85\lfloor 30\ 26° \rfloor$$
$$|V_d| = 437\ 85volts$$

This represents a voltage rise of 109 volts or 1 7 %

The voltage needed to maintain rated voltage at the load is now

$$V_{Sn} = V_d + V_{Ln}$$
$$V_{Sn} = 437\ 85v\lfloor 30\ 26° \rfloor + 6350v\lfloor 0° \rfloor$$
$$V_{sn} = 378\ 19v + j224\ 59v + 6350v$$
$$V_{sn} = 6728\ 19v + j224\ 59$$
$$|V_{sn}| = 6731\ 94volts$$

Load Flow of Sample Feeder - With Capacitor Added



III Introduction to PC's

Many years ago, International Business Machines marketed their first personal computer, or "PC" This was among the first computers which were small enough to fit on top of a desk, yet powerful enough to be useful in business While these first PC's are of little value compared to those we use today, it was the beginning of a very important trend in information technology

Rather than being very secretive about the design of this PC, IBM allowed other computer manufacturers to build and sell similar computers This is why today there are many manufacturers such as Compaq, Dell and Hewlett Pacard which build computers similar to the IBM PC

The set of instructions directing the computer to perform certain functions is called a **program, software** and also **applications** These are essential for a computer to be productive Without them the computer can perform almost no useful task

Since IBM's competitors build their PC's so that the same software will run on their machines as on IBM's models, these competitors' machines are said to be PC-compatible PC-Compatibles use the same printers, disk drives, cables, and modems also These devices are called peripherals

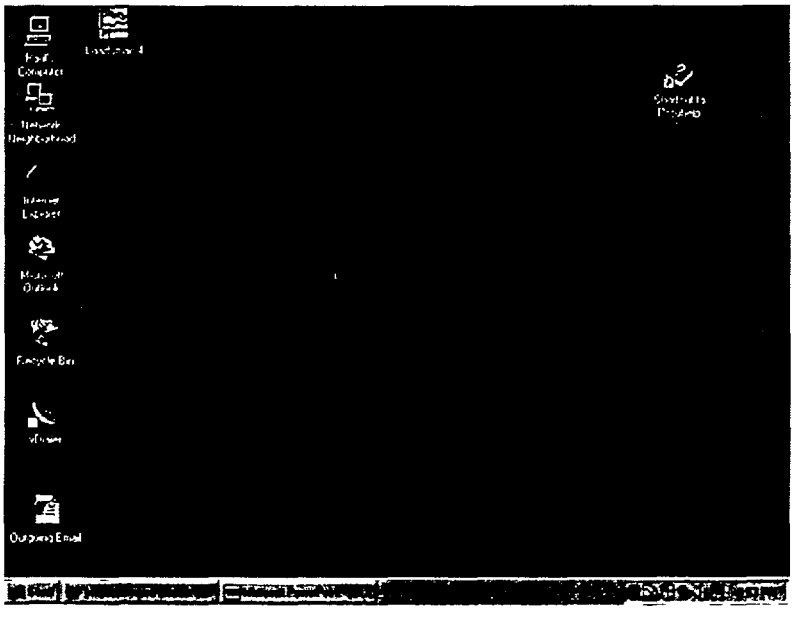
The focus of this training session is to learn how to make computer models of distribution feeders These models will be build using a type of software for the PC written by Stoner Electric called Distribution Primary Analysis/Graphics or DPA/G

We will also work to improve the participant's knowledge of other programs **Windows**, **Word**, and **Excel**, as necessary These programs are all products of Microsoft, Inc

Windows

Windows is a program which is designed to make it easier to access other computer programs and associated files It is a type of graphical menu

The computer ought to be set up to run Windows automatically upon power up At this point, Windows will display several small pictures, or **icons** Each icon represents a computer file, folder or program **Clicking** on an icon allows the user to access that file or folder or to run that program The mouse pointer can be moved over the associated icon and a double click will open it up



Activities

1 "Windows" folder

Double click on the icon "My Computer"
Choose the C drive
Find "Windows" in the list and double click on it

Windows is also a subdirectory in the computer's file system The files in the hard disk drive name "C " are grouped into various subdirectories In each of these subdirectories there can be some files or some subordinate subdirectories Inside of these subdirectories we can find again more files and subdirectories Double clicking on the files or subdirectories will open that file or subdirectories Double clicking on a program will run that program Double clicking on the "X" in the upper right corner of a window will close that window

2 Start Menu

Single-click on the start button at the bottom of the screen The Start menu will be displayed The start menu allows easy access to some of the most frequently used programs

3 Calculator Program

Click the Start button on the bottom left of the screen This gives a list of many programs and options available Choose "Programs" with a single click Subsequently choose "accessories" and "calculator" to run the calculator program Give it a try and then click the "X" to exit

4 Word

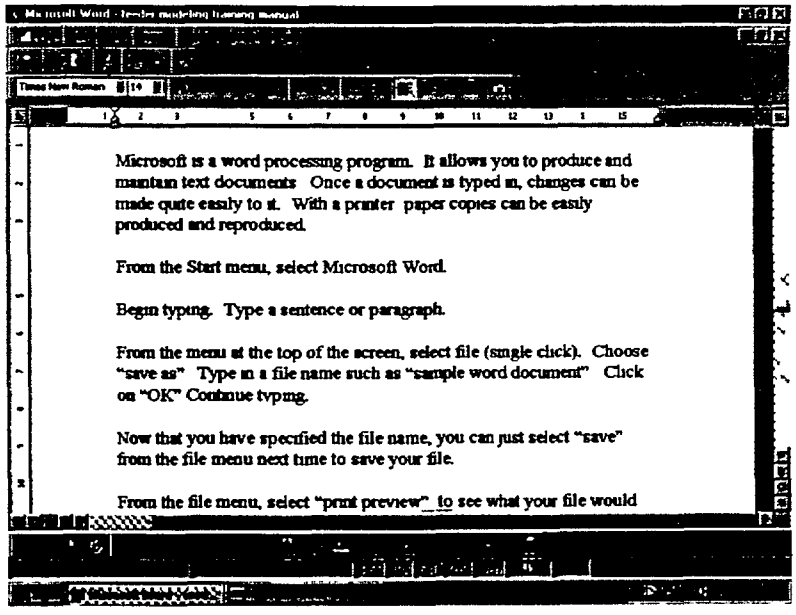
From the Start menu, choose Microsoft Word More time will be spent on this later "X" to exit

5 Excel

From the Start menu, choose "Programs" and then "Excel" More time will be spent on this later Click "X" to exit

Word

Microsoft Word is a word processing program It allows you to produce and maintain text documents Once a document is typed in, changes can be made quite easily to it With a printer, paper copies can be easily produced and reproduced



Activity

From the Start menu, select Microsoft Word

Begin typing Type a sentence or paragraph

From the menu at the top of the screen, select file (single click) Choose "save as" Type in a file name such as "sample word document" Click on "OK" Continue typing

Now that you have specified the file name, you can just select "save" from the file menu next time to save your file

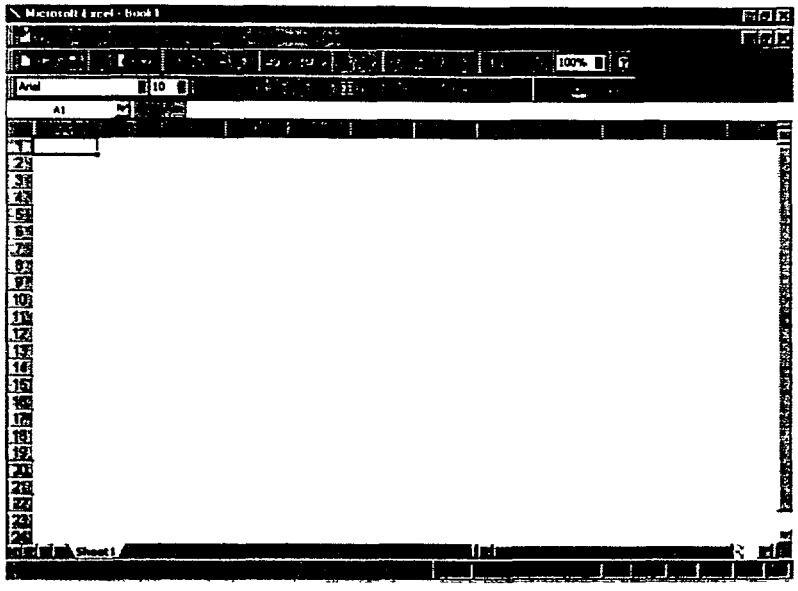
From the file menu, select "print preview" to see what your file would look like.

If you have a printer, select "print" from the file menu Select "OK" and retrieve page from printer

Continue Typing When you are done, save the file one final time and exit the program with "X" or "exit" from the file menu

Excel

Microsoft Excel is used to manipulate numerical data Number and text are organized in rows and columns This can be a very convenient way to store and display your data



Activity

From the Start menu, choose Programs/Excel Move the **cursor** around to the various **cells**

In Cell A1, type the number 25, which can represent today's high temperature

In cell A2, type the number 23, which can represent yesterday's high temperature

In cell A3, type the number 31, which can represent the high temperature from two day's ago

In Cell A5, type

=(+A1+A2+A3)/3

This will fill cell A5 with the average temperature of the last three days

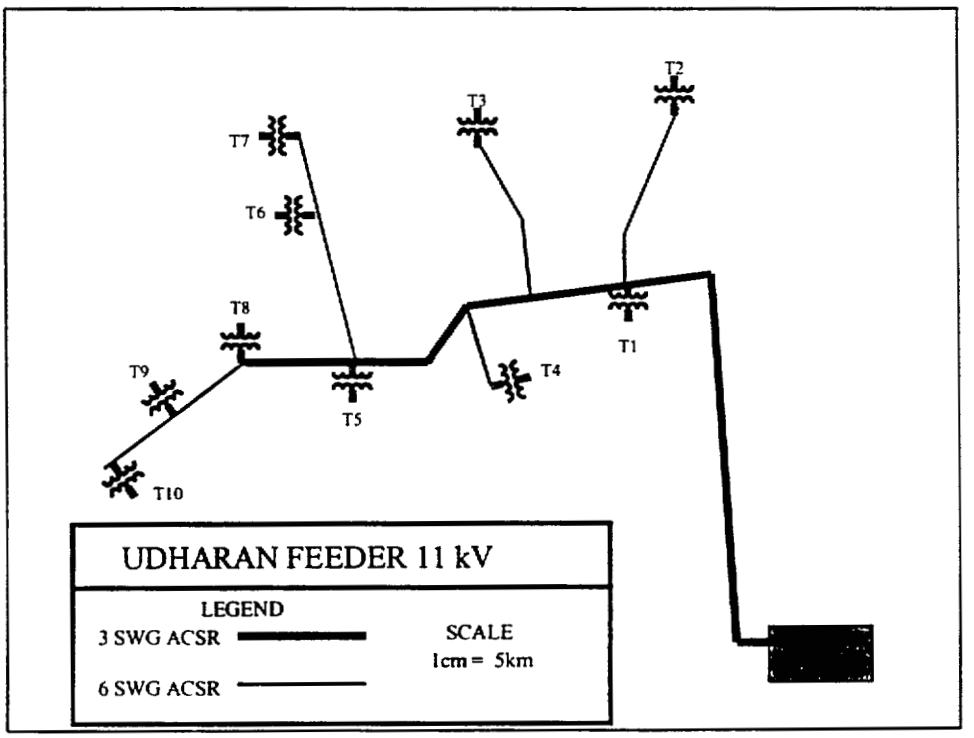
From the file menu Select "save as" Save the file with a name such as "temperature study"

After any other changes are made, save the file from the file menu

Exit using "x" or "exit" from the file menu

IV Test Case – Udharan Pur Feeder

Consider the following HT diagram of our sample feeder, the "Udharan Pur" feeder

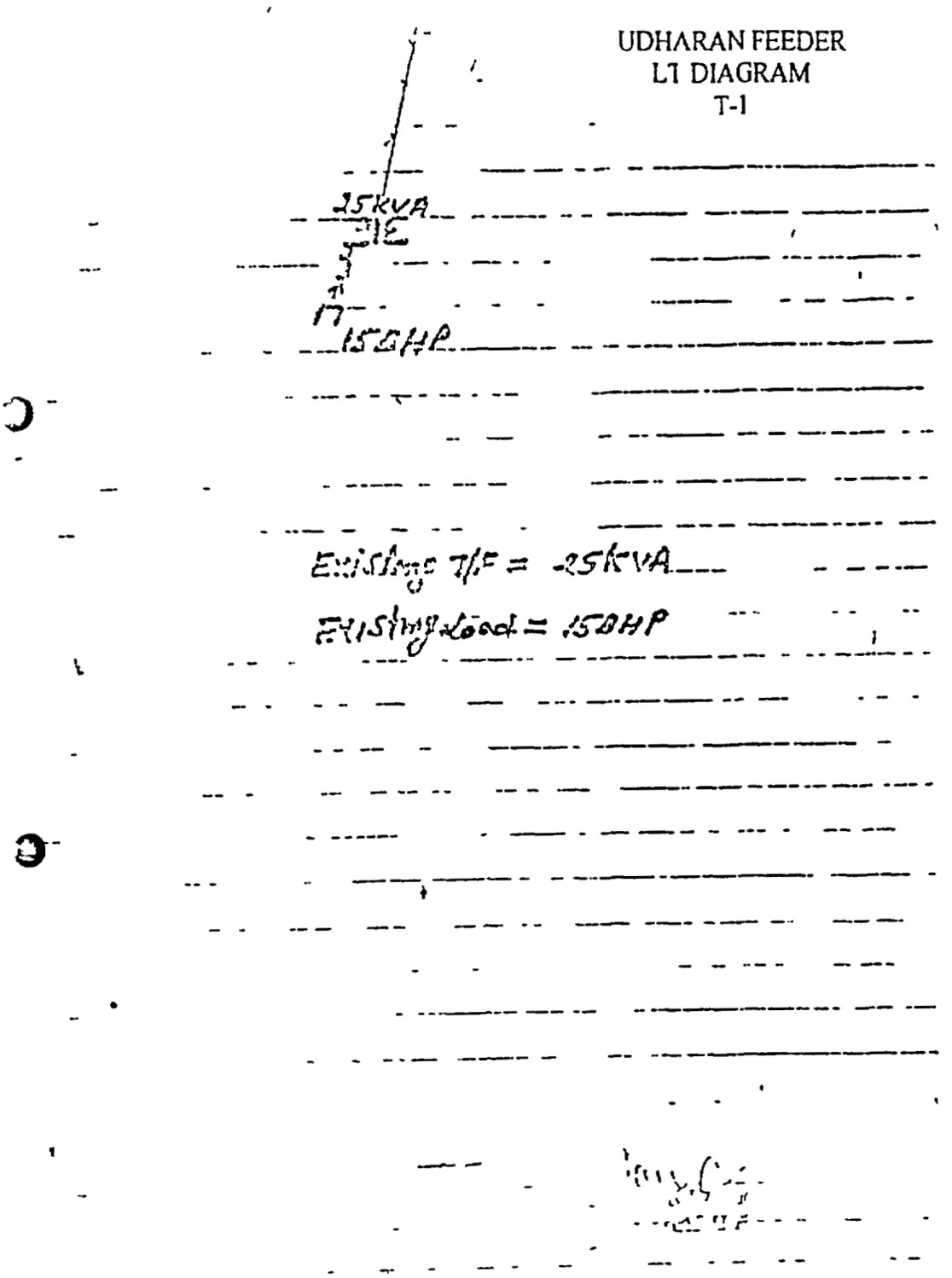


As mentioned earlier, the software which will be used to model this sample distribution feeder is called Distribution Primary Analysis/Graphics, produced by Stoner Electric Screens from this software are shown so the user will know in what format the user must prepare and enter the data

LT Diagrams

In order to study the load on the Udharan feeder, we can look at the LT diagrams, if available, for each distribution transformer on the feeder The following pages contain such diagrams

UDHARAN FEEDER
LT DIAGRAM
T-1



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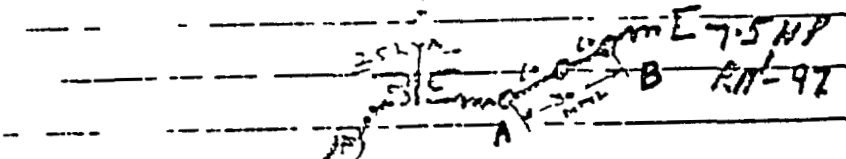
UDHARAN FEEDER
LT DIAGRAM
T-2



Size of Conductor 6SWG (30 mm²)

Existing T/F = 25KVA

Existing load = 15 HP

Total length of LT line = 120 mtr

S.R No	LOCATION	TOTAL LENGTH	SIZE OF CONDUCTOR
1	A TO B	120 MTS	30 mm²

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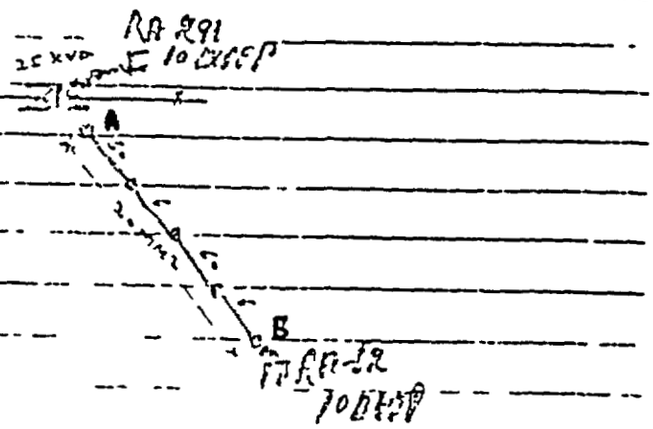
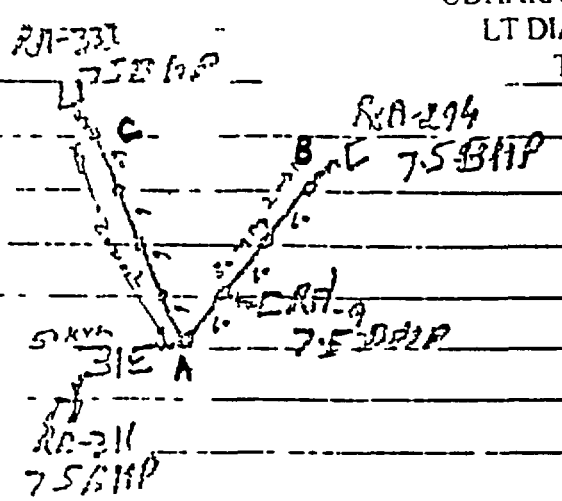
UDHARAN FEEDER
LT DIAGRAM
T-3



SP No	LOCATION	TOTAL LENGTH	SIZE OF CONDUCTOR
I	A TO B	240 mts	30 mm²

UDHARAN FEEDER
LT DIAGRAM
T-4



Size of Conductor = 6SWG.

Existing T/F = 50 KVA

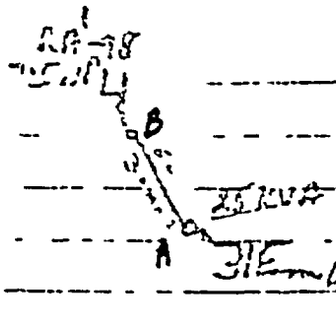
Existing load = 30 BHP

Total length of LT line = 420 mtrs

SR No.	LOCATION	TOTAL LENGTH	SIZE OF CONDUCTOR
1	A TO B	180 mtr	30 mm²
2	A TO C	240 mtr	30 mm²

HC of Station

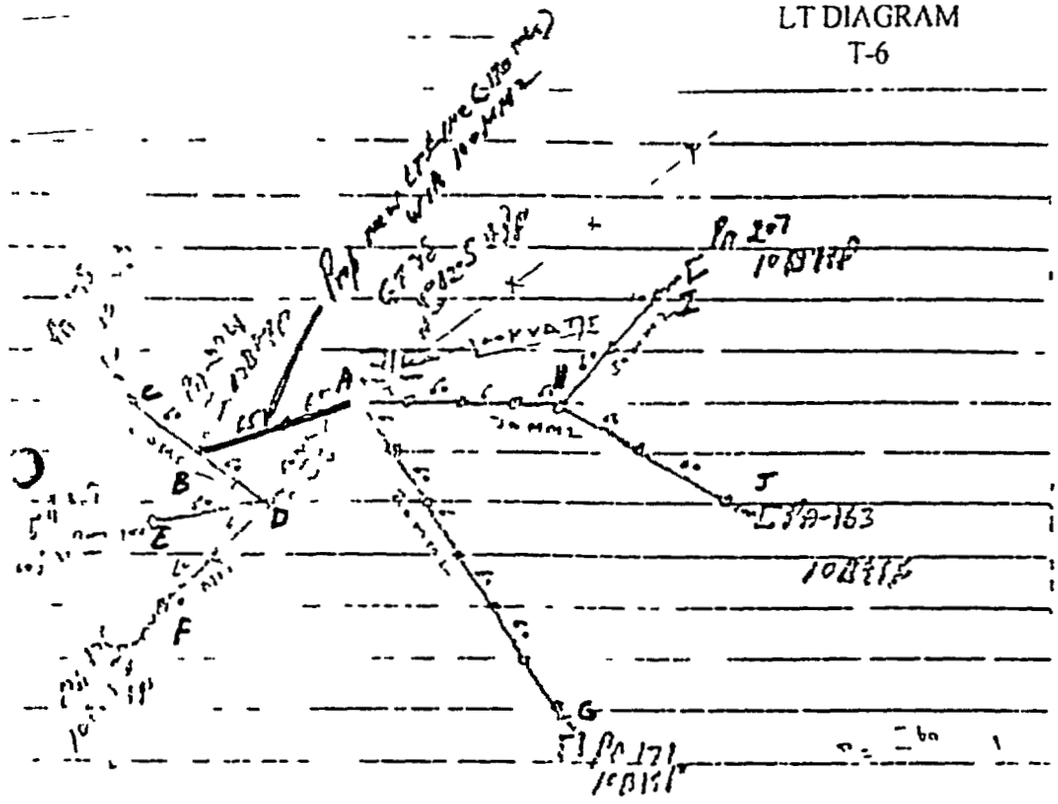
UDHARAN FEEDER
LT DIAGRAM
T-5



Size of Conductor 6SQ.G.
Existing T/F = 25KVA
Existing load = 150HP
Total length of LT line - 60mtr

SR No	LOCATION	TOTAL LENGTH	SIZE OF CONDUCTOR
1	A TO B	60 Mtr	70 mm²

UDHARAN FEEDER
LT DIAGRAM
T-6



Size of Conductor = 65 sq.mm (30 mm²)

Existing TF = 100 KVA

Existing load = 82.5 AMP

Total length of LT line = 1260 mtrs

	AFTER IMPROVEMENT
	Existing TF = 100 KVA
No. of line	Load = 82.5 AMP
Size of LT line - 65 mm² (65 sq)	LT-Line = 133.0 mtrs

S.No.	LOCATION	TOTAL LENGTH	SIZE OF CONDUCTOR
1	A To B	130 mtrs	100 mm²
2	B To C	[illegible] "	30 "
3	A To J	[illegible] "	30 "
4	D To E	[illegible] "	30 "
5	J To F	120 "	30 "
6	J To G	300	30
7	A To H	210	30 "
8	H To I	120 "	30 "
9	H To J	120 "	30

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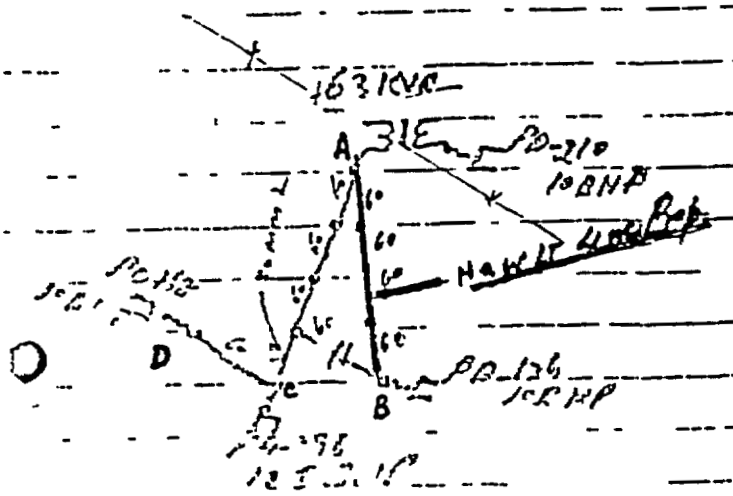
UDHARAN FEEDER
LT DIAGRAM
T-7



Size of Conductor = 65 sq. (30 mm²)
Existing T/F = 63 KVA
Existing load = 40 BHP
Total length of LT line = 360 mtr.

	AFTER IMPL
1	T/F Exist = 63 KVA
2	Load = 40 BHP
3	LT Line = 540 mtr

S.No	LOCATION	LENGTH	SIZE OF CONDUCTOR
1	A-B	240 mt	100 mm²
2	A-C	240 "	30 mm²
3	C-D	60 mt	30 "

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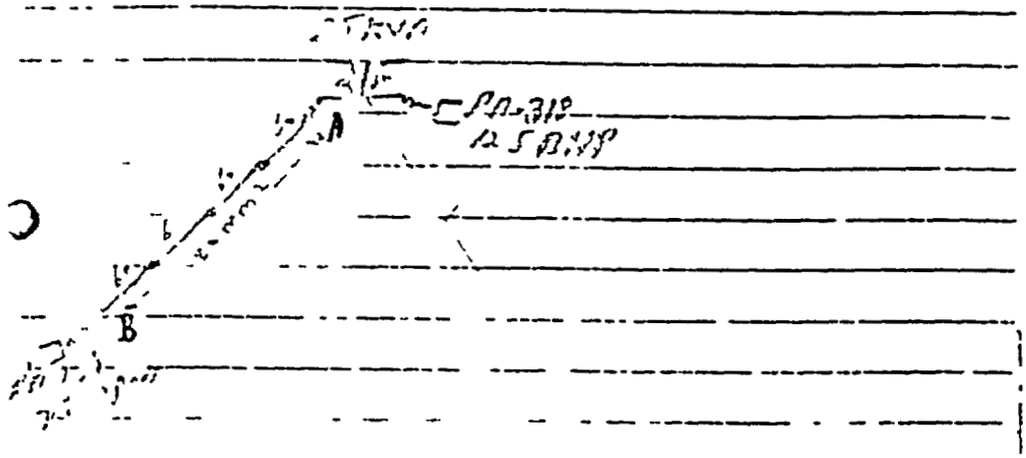
UDHARAN FEEDER
LT DIAGRAM
T-8



Size of Conductor for 6SWG (30mm²)
Existing TF = 25 KVA
Existing load = 25 BHP
Total length of LT line = 240 metre

Sl. No.	LOCATION	LENGTH	SIZE OF CONDUCTOR
1	A-B	240 Mtr	30 mm²

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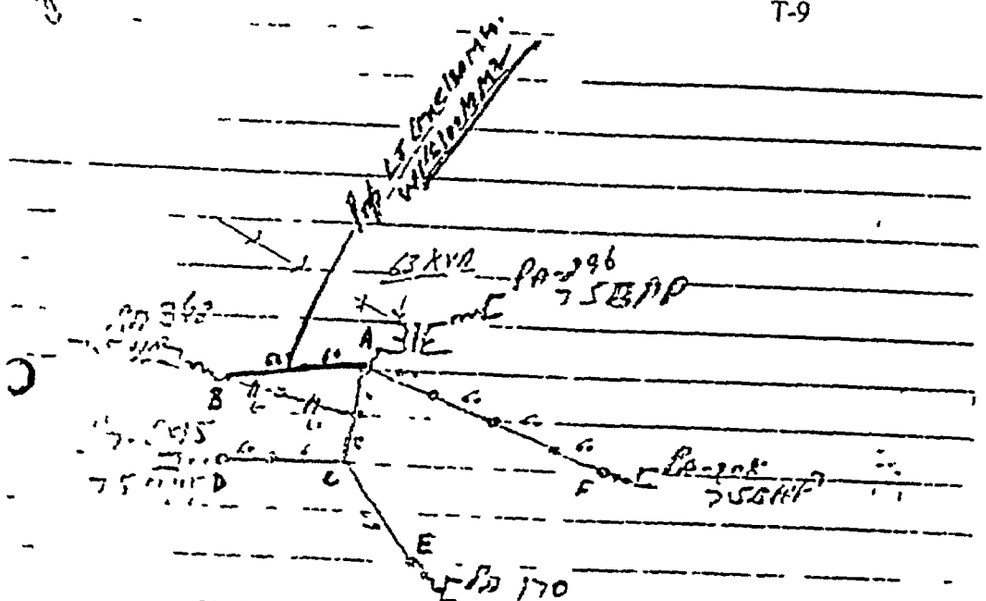
UDHARAN FEEDER
LT DIAGRAM
T-9

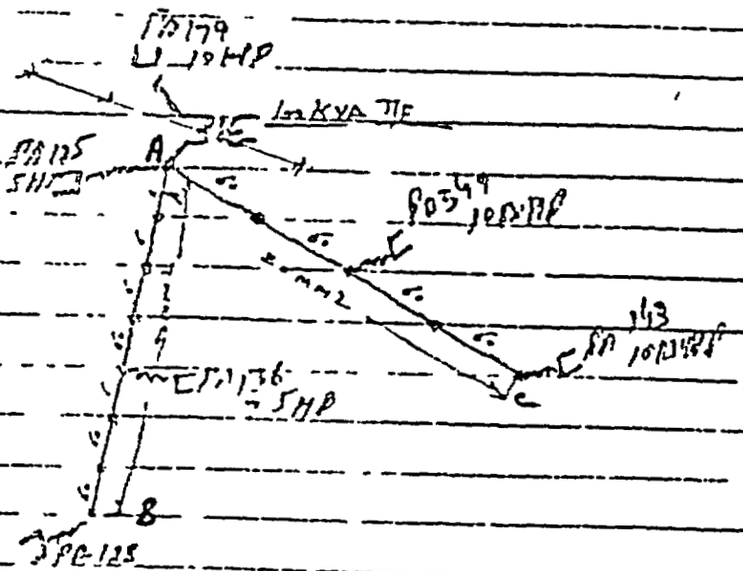


Size of Conductor = 6 SWG.
Existing T/F = 63 KVA
Existing Load = 47.5 BHP
Total length of LT Line = 660 mtr

BEFORE IMP	AFTER IMP
[illegible]	1 Exist T/F = 63 KVA
[illegible]	2 Load = 47.5 BHP
[illegible]	3 LT Line = 6 Conds

LOCATION	LENGTH	SIZE OF CONDUCTOR
A – B	120 mtr	100 mm²
A – C	120 "	30 "
C – D	120 "	30 "
C – E	60 "	30 "
A – F	240 "	30 "

UDHARAN FEEDER
LT DIAGRAM
T-10

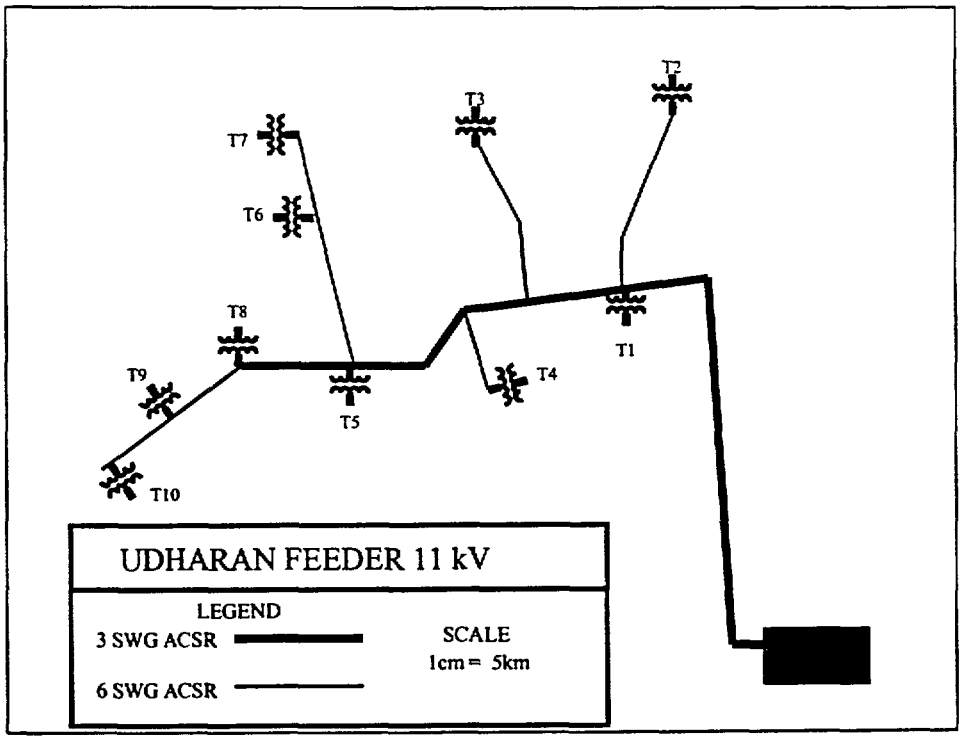


Each Span 60 mts
Size of Conductor = 65 Sq. mm
Existing TF = 100 KVA
Existing Load = 52.5 HP
Total length of LT Line = 660 mts

SN.	LOCATION	LENGTH	SIZE OF ACSR
1	A-B	420 mts	30 mm²
2	A-C	240 "	30 mm²

Activity 1 Drawing Feeder Model in DPA/G

Each participant will begin to model the feeder using the DPA/G software



BEST AVAILABLE COPY

The following step by step procedure will help to get started with the DPA/G software During the course of following this procedure the user can learn about other options and functions of the software by choosing those options of interest from the menu

Start by double-clicking on the "Shortcut to DPA/G" icon on the desktop

Click on "OK"

On the EDIT menu, choose SKETCH

Click on "Feeder" and "Create New" to create a new feeder

Click on "OK, Sketch"

Give the name of the feeder, such as "Udharan-pdl"

Place the mouse at the coordinates (8 8,1) on the sketch screen

With the mouse, draw the first section of the feeder coming out of the substation

Give the name of the first section, for example l01 Click on "OK"

On the edit menu, SAVE the sketch

On the ZOOM menu, choose OUT CONTROL-Z does the same thing This will reduce the image of the feeder

Double-click on the name of the first section

Choose CHARACTERISTICS

Confirm the data regarding that first section Make changes where necessary SAVE and EXIT the Charateristics Editor EXIT the section editor

Build can be done later Click "OK"

On the EDIT menu, SAVE the sketch

Close the Sketch Window

On the EDIT menu, choose FEEDER RECORD

Update the fields regarding the new feeder Choose the "sample" substation, a L-L voltage of 11 kV, with a bus voltage of 415 volts on a 415 volt basis

Click on SAVE

Exit the Update Feeder Record dialog box

On the Config Menu, Choose BUILD

Use the "Selected Feeders" option Select Feeder from the sample substation

Edit Sketch Use the "EDIT EXISTING FEEDER" option Select Feeder from the list under those in the sample substation Click on "OK, Sketch"

Add additional sections

SAVE Sketch

Double click on each section and enter the proper distance for each

The load on each of the transformers on the Udharan Feeder is given in Brake Horse Power (bhp), but must be entered into DPA/G as single phase kw and kvar loads

If E_f is the efficiency of a motor, P_m is the mechanical power output at the motor's rotor in bhp, and P_e is the electrical power drawn by the motor, then

$$P_e = \frac{P_m}{E_f} \times 746 \quad (in\ kw)$$

If $P_{1\phi}$ is the single phase electrical power drawn by the motor, then

$$P_{1\Phi} = \frac{P_e}{3}$$

If $S_{1\phi}$ is single phase complex power (in kVA) drawn by the motor and PF is the power factor at which the motor runs, then

$$|S_{1\Phi}| = \frac{P_{1\Phi}}{PF} \quad (in\ kVA)$$

If ϕ is the phase angle between the motors phase current and phase voltage, then

$$\Phi = \cos^{-1}(PF)$$

If $Q_{1\phi}$ is the single phase reactive power drawn by the load, then

$$Q_{1\Phi} = S_{1\Phi} \bullet \sin\Phi \quad (in\ kVAR)$$

Assuming the motors on the Udharan feeder have an efficiency is 8 and the power factor is 8, calculate $P_{1\phi}$ and $Q_{1\phi}$ for each transformer

We can add this data to our model

For each transformer, double click on the section name where this load ought to be modeled

Click on the "Load" button

Add the loads under the spot load category Indicate if this spot load is at the load side, source side or middle of the section

Activity 3 Running Load Flow

Click on the Analysis menu Choose the type of analysis you would like to use

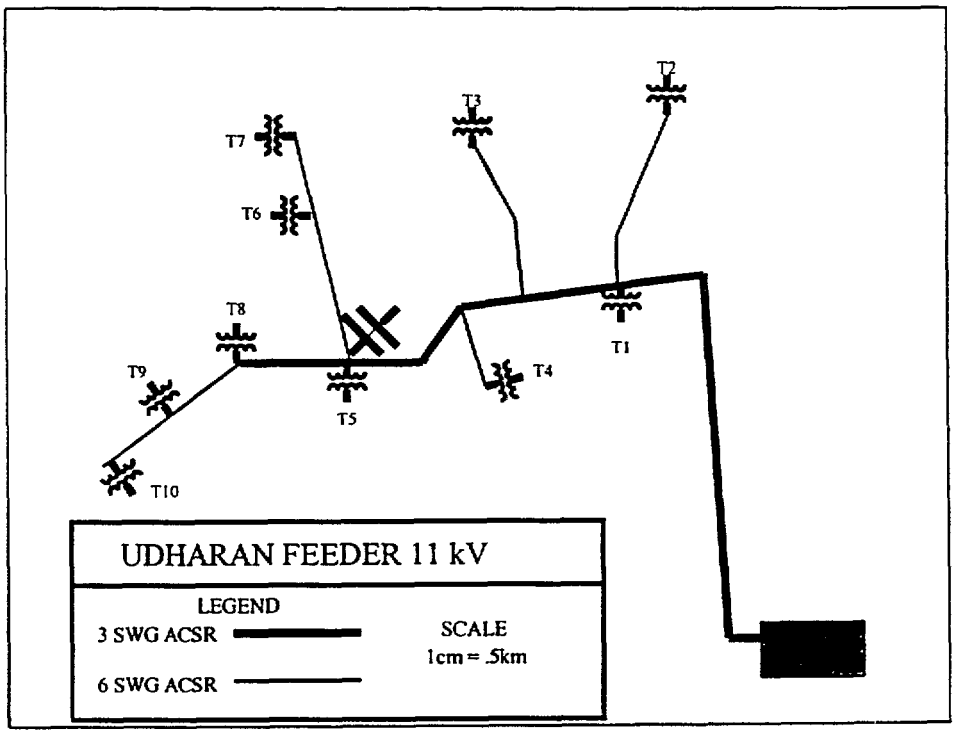
Activity 4 **Output from Loadflow**

DPA/G provides reports showing voltage on each part of the circuit, current through each branch in the circuit, and losses throughout the circuit

On the analysis menu, choose "balanced analysis" Study the results of this analysis

Activity 5 Placing Capacitors

One common function of feeder modeling and loadflow analysis software is to see the effect that adding reactive compensation can have A 100 KVAR capacitor can be added at the location shown Use the Change Data option on the Edit menu



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V Workshop Modeling Local Feeders

Materials Needed Feeder HT diagrams, transformer data load data, LT diagrams

APPENDIX - IV

SWITCHYARD WALKDOWNS & THERMO-VISION SCANS

FOR

(i) PINJORE

(ii) BABYAL

(iii) PEHOWA

(iv) KARNAL

(v) NILOKHERI

(vi) MADHUBAN

(vii) HISAR 220 KV

(viii) BEER

(ix) BEER (REPEAT)

(This was an integral part of the Training Program)

IRg INTERNATIONAL RESOURCES GROUP

INDIA

SEPTEMBER 1998 – DECEMBER 1998

Substation Inspections

During the course of the training program, the following switchyards in Haryana were inspected with the individual training groups The engineer in charge of each substation is indicated

- Pinjore - Balraj Sheoran
- Babyal - B R. Garg A E E
- Pehowa - T C Gupta E E Tel 01741-20038 or 01741 - 20041
- Karnal - K L Jawa
- Nilokheri - C D Pasricha, AE/SSE, 132 kV S/Stn, Nilokheri (Karnal)
- Madhuban - Inder Jit Leekma - S S E Tel 257871 (O) 262524 (R)
- Hisar - Ram Dhan A E /S S E
- Beer - Ram Dhan A E /S S E

Each of the above switchyards were walked-down by the individual training groups and the noted deficiencies were listed as shown on the following sheets

Also thermo-vision scanning was performed at each switchyard except Babyal and Pehowa At Pinjore, no hard copies of the scans were made available for this report

PINJORE SWITCHYARD

Note Scanning was done but hard copies were not made available

Pinjore Substation Deficiencies

Lightning arresters missing on both 132 kV & 66 kV sides of transmission power transformer

Ground strap on 66 kV CT structure broken

Overgrown weeds on crushed rock surface

Transformer foundations have no catch basins

Overhead shield wire coverage not complete

Hot spots detected on some connections, jumpers, isolator switch jaws (Note scanning was performed by BBMB, as a favor to HVPNL, to enable the trainees to get a feel for what the scanner could do No hard copies of scanned images were furnished)

Pf meter on 11 kV capacitor bank defective

Only about 18 inches clearance between 132 kV relay panels and block wall Insufficient space

No M&R diagrams available

Capacitor units in the banks were missing fuses

Semaphores on mimic bus panels were non-operational

Mimic bus color for same voltage level changes between panels

Many 'status' indicating lights were burnt out

Not all ammeters on switchgear panel were functional

Missing and/or unconnected lightning arresters on outgoing 11 kV line H-frame terminal structures at cable to OH line interface

11 kV cables in switchyard were lying on ground surface & not trenched

Cable trenches were missing covers

Newly run cables were run along the ground surface and haphazardly entered trenches over the lip and not through sidewall sleeves

Cable from kiosks or terminal boxes from equipment were exposed and not run in conduits

PVC cables exposed to sunlight

Control cables run on the top of metal wire-ways instead of inside of

CT ratios and actual connected ratios were not indicated on switchgear control panels

Lightning arrester leakage current monitors were corroded and not functional

BABYAL SWITCHYARD

Note No scanning was done as contractor had damaged his scanner and it was out for repairs

Babyal Substation Deficiencies

One 66 kV line is out of service Is one line adequate?

Wave trap is on the dead line Is communication adequate?

No lightning arrester on the 66 kV incoming lines Sphere gaps DO NOT provide adequate protection

Overhead shield wire is needed There are areas of the substation unprotected from direct lightning strikes

Auxiliary contacts on 66 kV isolators are not working Indicators must therefore not be working

No ground mat under isolator operating handle

Crushed rock sunk leaving dirt and weeds on the surface

B-phase of line breaker (66 kV) is jumpered out

Charging motor not operational in 66 kV line breaker, therefore breaker is non-automatic Has protective zone and tripping been modified accordingly?

Breaker control not working

Improper coordination of arc gaps for lightning protection

Bolt on one particular connector was not the correct material and has corroded

Bending radius of jumpers are too small

No rod gaps on breaker isolator No 05

Open strands on jumper wires

Lightning arresters should be mounted closer to transformer

Lightning arrester surge counter not operational

Transformer tank oil level indicator not clearly marked

Manufacturer's O & M manual not on site

Transformer LTC can't operate under load

Improper spacing on 11 kV cables at transformer Stress cones too close

Control cables not properly installed in trench

No oil catch basin for transformer oil spillage

11 kV PILC cables are leaking oil at switchgear

Wrong type of bolts on mounting of switch handle on cap bank They have become corroded

Indicating lamps not working throughout the entire control room

CT ratio marked on ammeter not consistent

Power factor running at 75 leading Meter is defective

On breaker, meter shows no load, no light is on, target on breaker not visible Breaker is CLOSED

On another breaker, meter shows no load, no light is on, target on breaker shows OPEN while breaker is CLOSED

Semaphore indicator on breaker is in wrong position, wrong indication

No 11 kV lightning arresters on riser poles

Improper spacing on stress cones at 11 kV side

PEHOWA SWITCHYARD

Note No scanning was done The scanner was still out for repairs

Pehowa Substation Deficiencies

Crushed rock surface is in poor shape

Many jumper wires have separated stranding

Many wires with tight bending radius

No shielding on control cable in metering cabinet

Bolts missing on connectors

Covers missing on trenches

11 kV cable laying on ground

Indicating lights in transformer control cabinet burnt out

Transformer foundations containment area not large enough, and openings in walls

Control cable not properly covered, bent tightly, with rocks piled on top

Winding temperature reading lower than oil temperature on transformer Defective WTI

Trench cover sitting directly on cables

No lightning arrester on distribution lines

No bottom arm on arcing horns

One transformer has no impedance stamp

Opening for cables on transformer control cabinet not properly sealed Squirrels are nesting inside

Capacitor bank out of service

Indicator lights on breaker panels not working

No fuse protection on battery cables

Semaphore on control panel not working

CT ratios on 220 kV panel not clearly marked

KARNAL SWITCHYARD

Karnal Substation Deficiencies

Covers missing or broken on trenches

33 kV cables exposed (not buried)

Door open on CVT control box

Shield wires not adequate on 220 kV and other areas

Squirrel nest in control panel

Crushed rock protection deteriorated or not existent

Lightning arrester should be closer to transformer

Poor stranding on jumper wires

Arcing horns missing on disconnect switch

High loss jumper on 132/33 kV transformer

No stress cone on 11 kV cable

33 kV CT has wrong bolts on connectors and so they are corroded

Bimetal connector needed on CT

Sharp bending radius on connector

Cap bank out of service due to lack of CT

Lightning arrester needed on cap bank

Control House

Semaphores not working

No fuses on station battery cables

66 kV Ladwa Barbain feeder - ammeter not working

132/11 kV T-3 pf meter not working, frequency meter not working

11 kV Incoming No IV - power factor meter not working

Battery Charger - Ammeters not working

220 kV Control House

No fuses on battery cables

Indicating light not working on 220/132 autotransformer T-4 panel

Trip circuit CKT-2 faulty

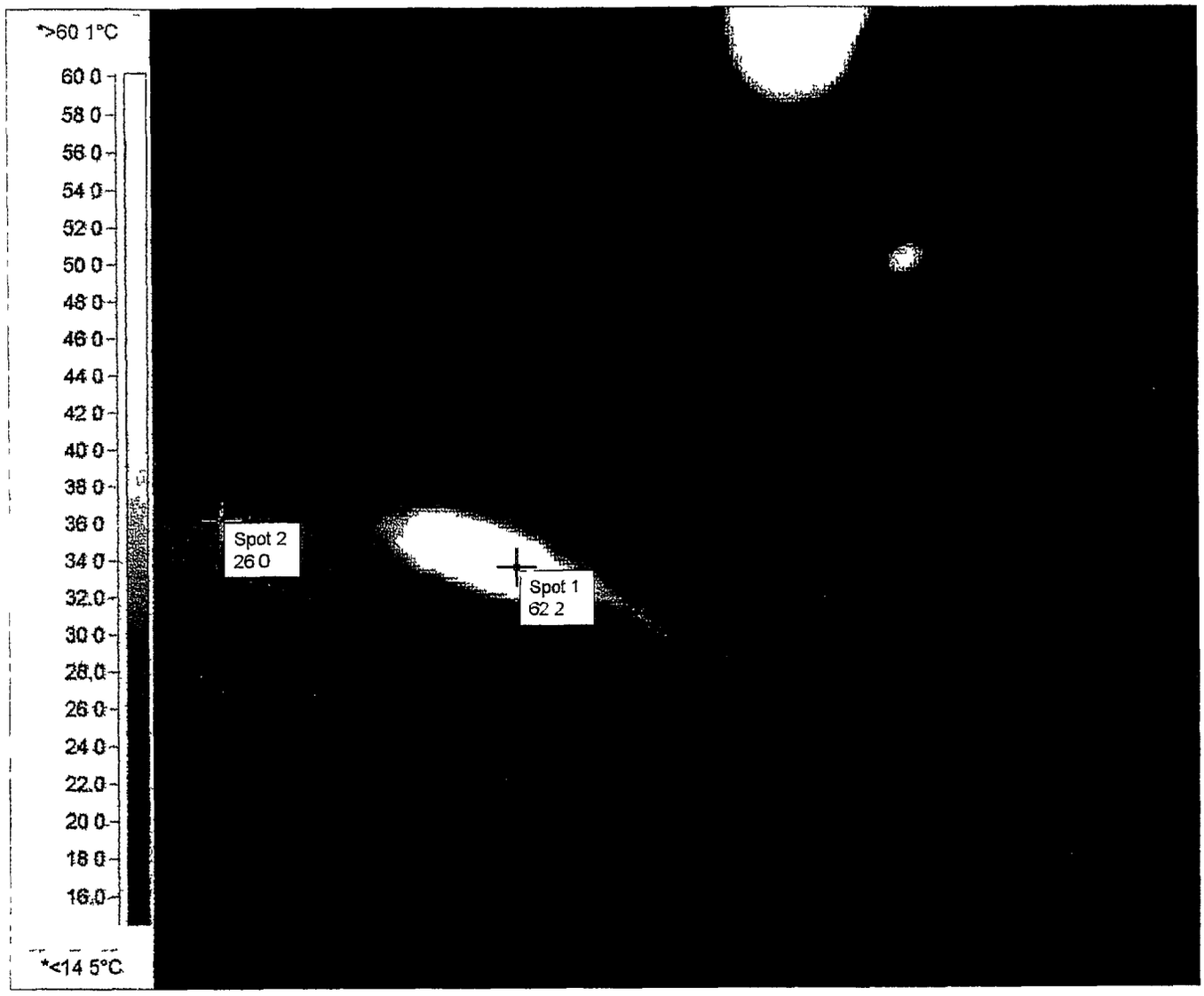
Yellow light should be a blue light for spring charge indicator

Semaphore not working on T-3 220/132 100 mva transformer panel

Door opens without interlock on LV breakers

CT jumper of MOCB D-1 Red phase hot

D14 TIF



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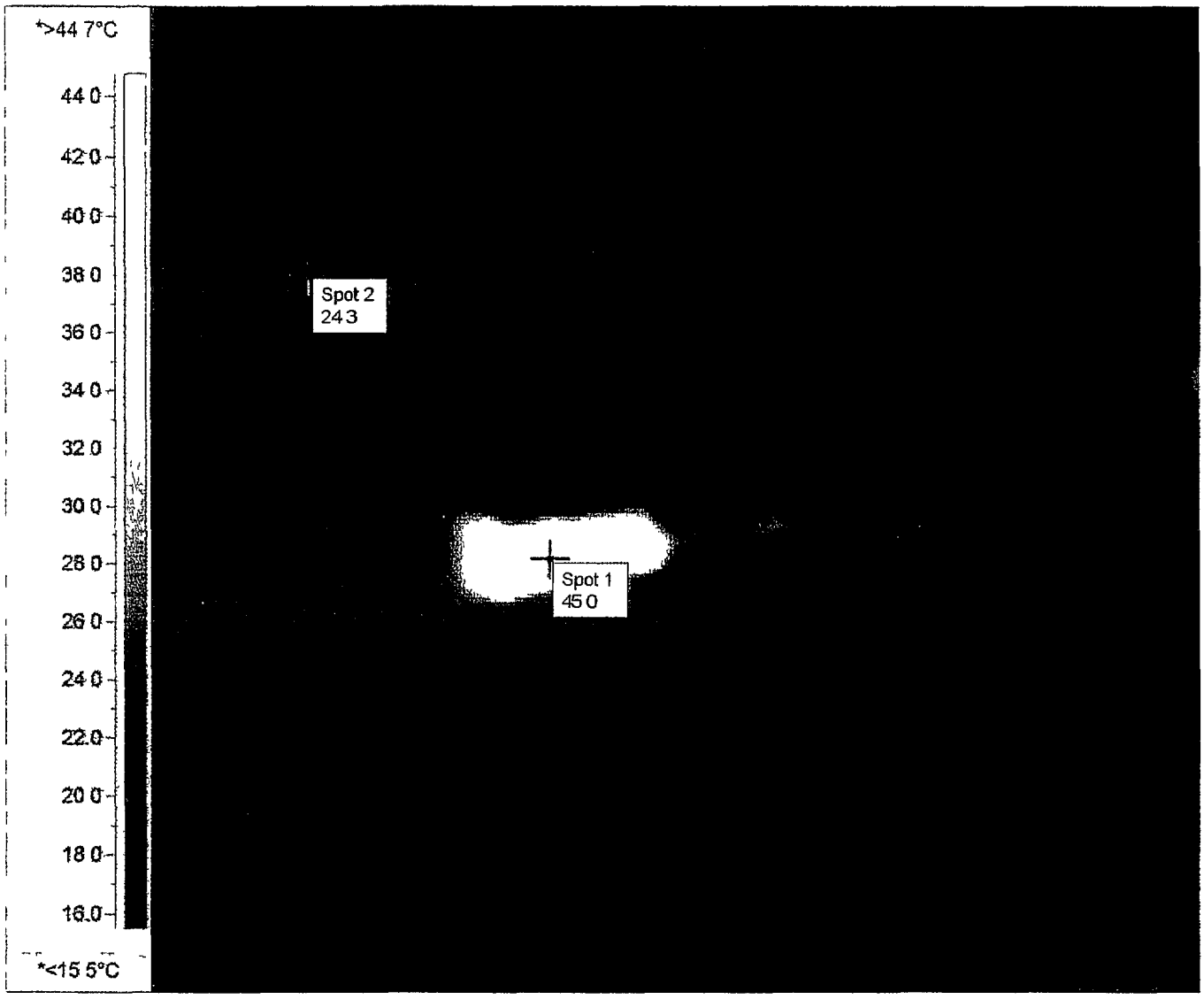
CT jumper of MOCB D-5 ~~Red~~ Hot

E02 TIF



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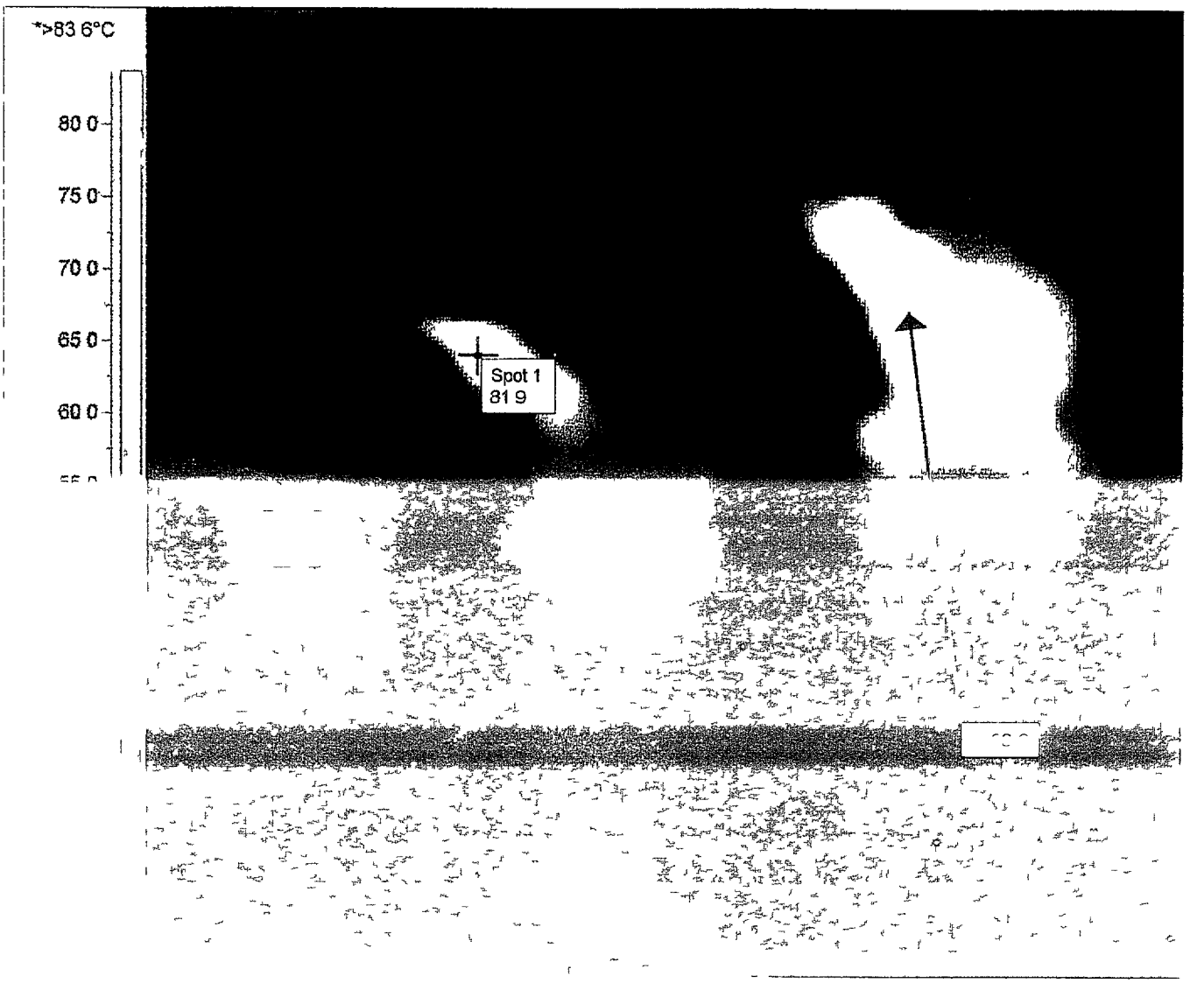
Circuit Breaker MOCB D-7 NDRI-Staundı

D12 TIF



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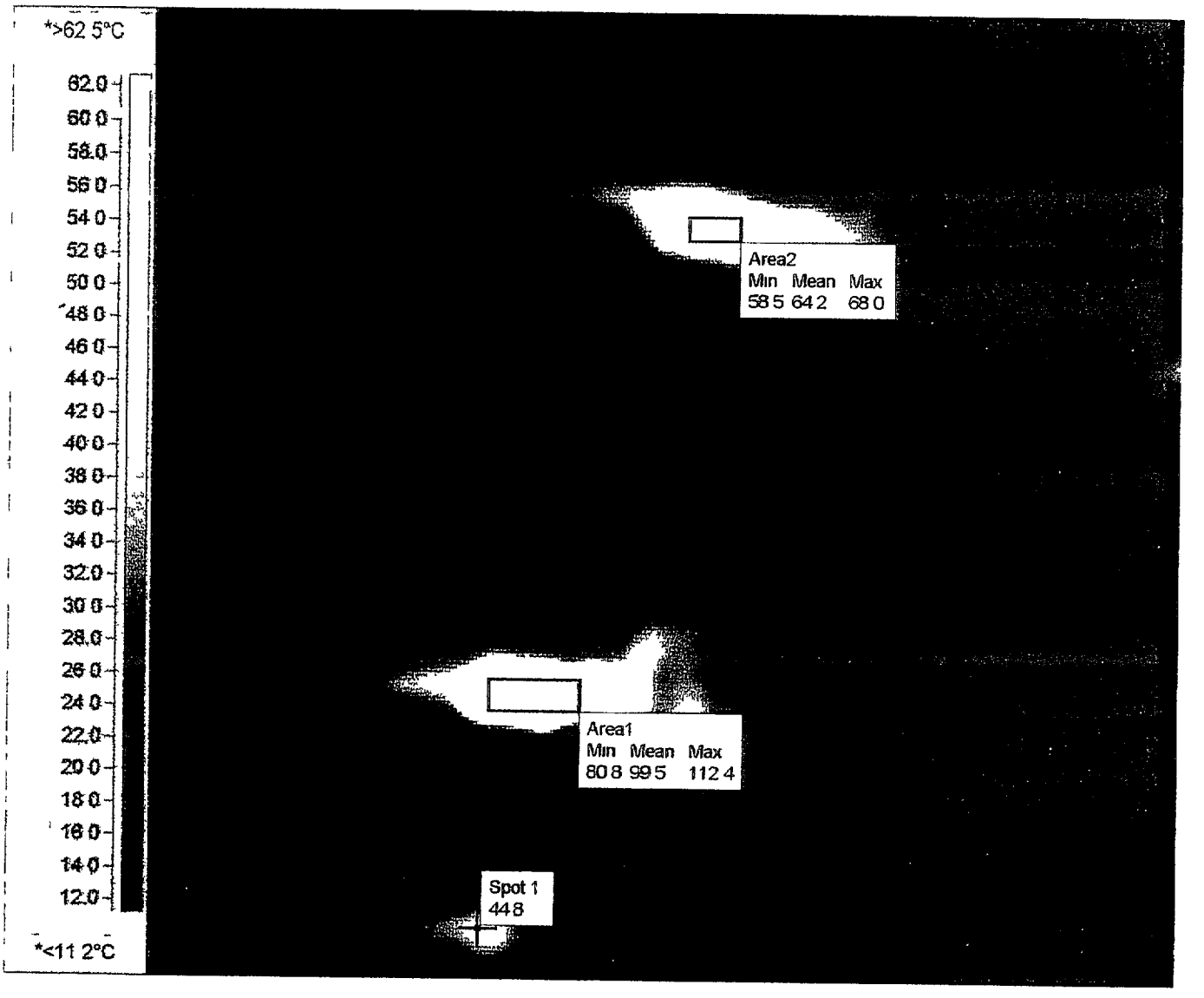
Malipur Jumper between CT & Isolator ~~Red~~ Hot

E05 TIF



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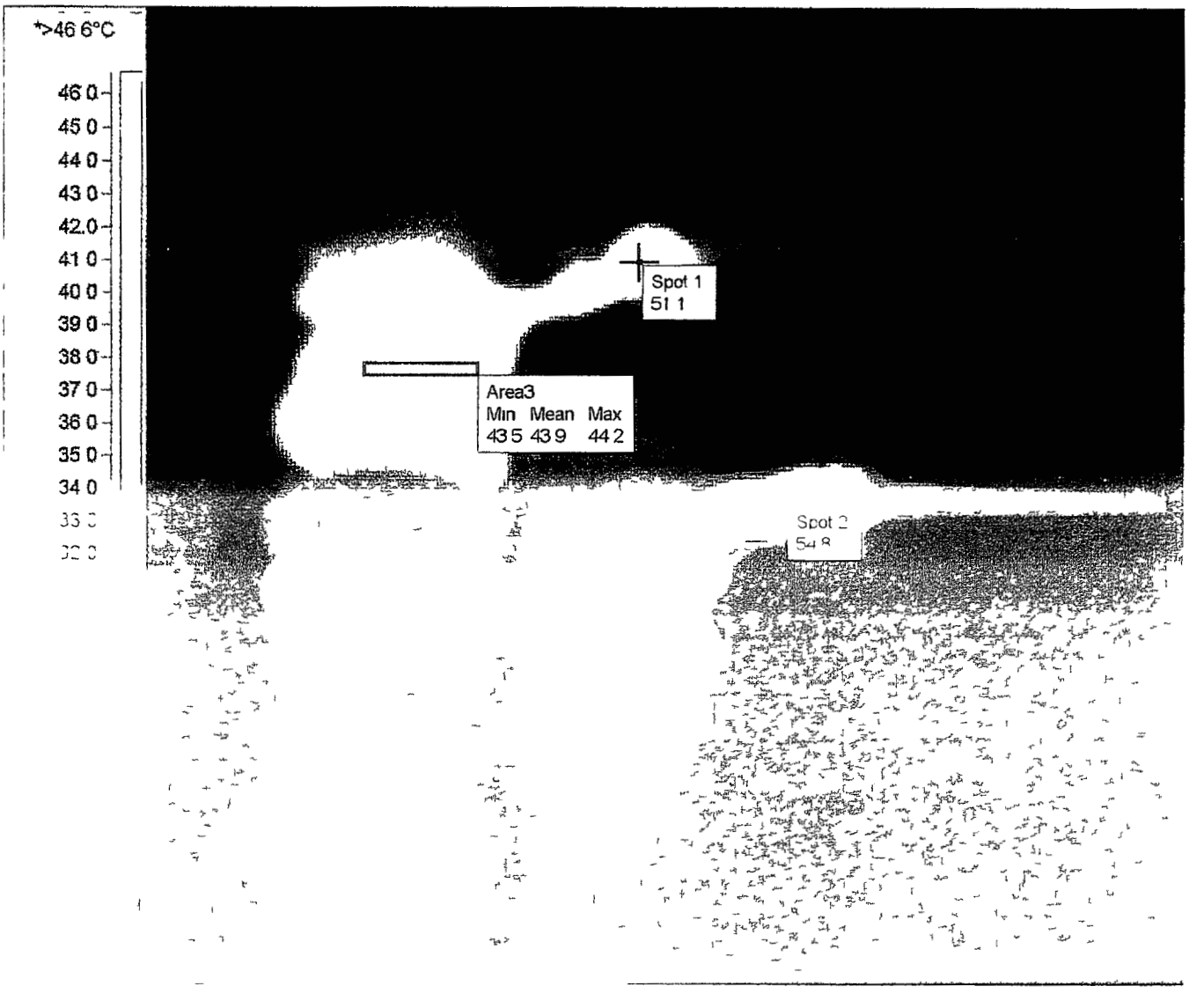
MOCB of 33 KV D-7 NDRI-Staundı

E07 TIF



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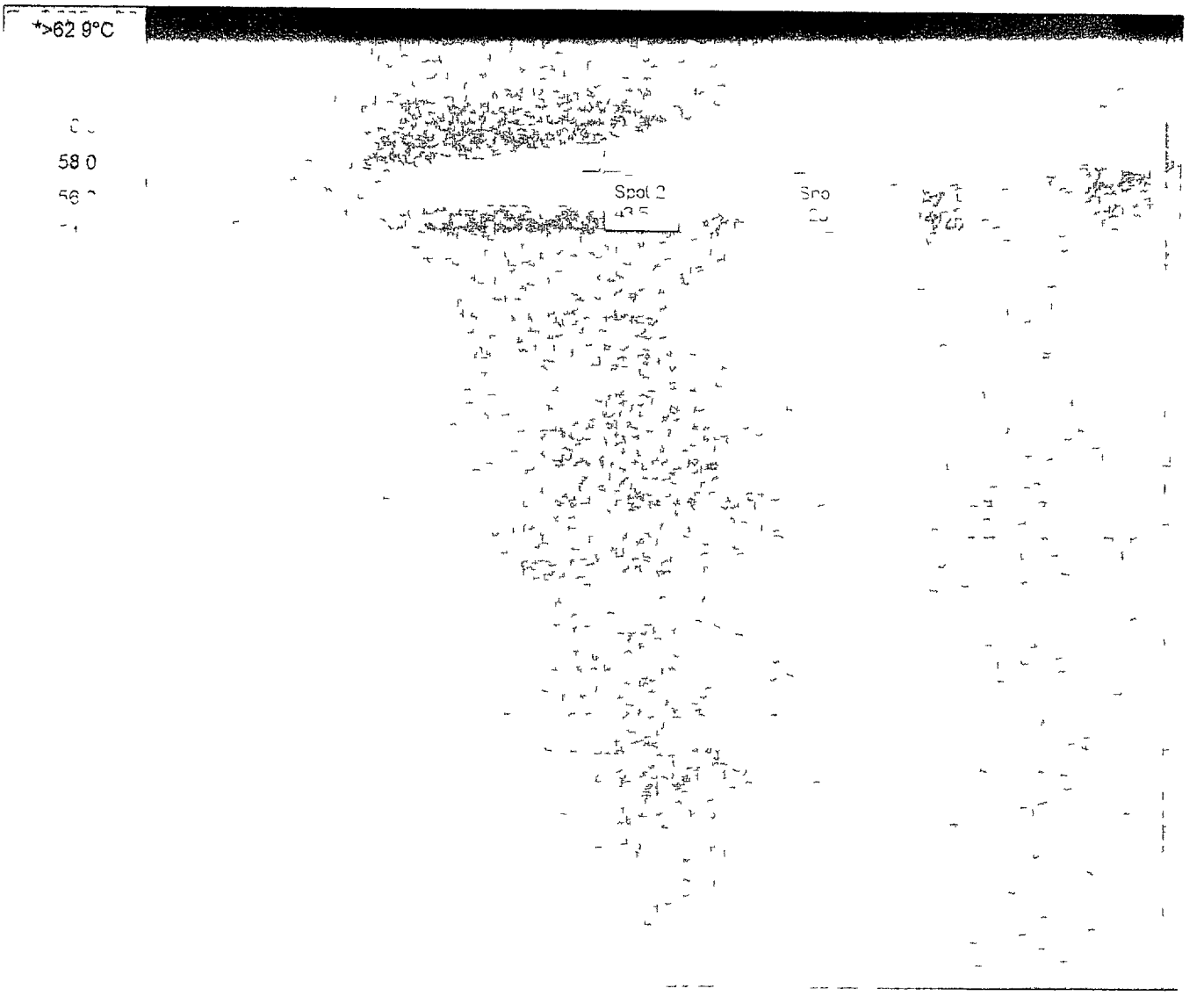
33 KV MOCB D-5 Newal-Gheer

D16 TIF

inframetrics TherMonitor 95 12/2/98 1 21 34 PM

Isolator no 105 Isolator blade hot of 132/33 kV T-1 TF

D08 TIF



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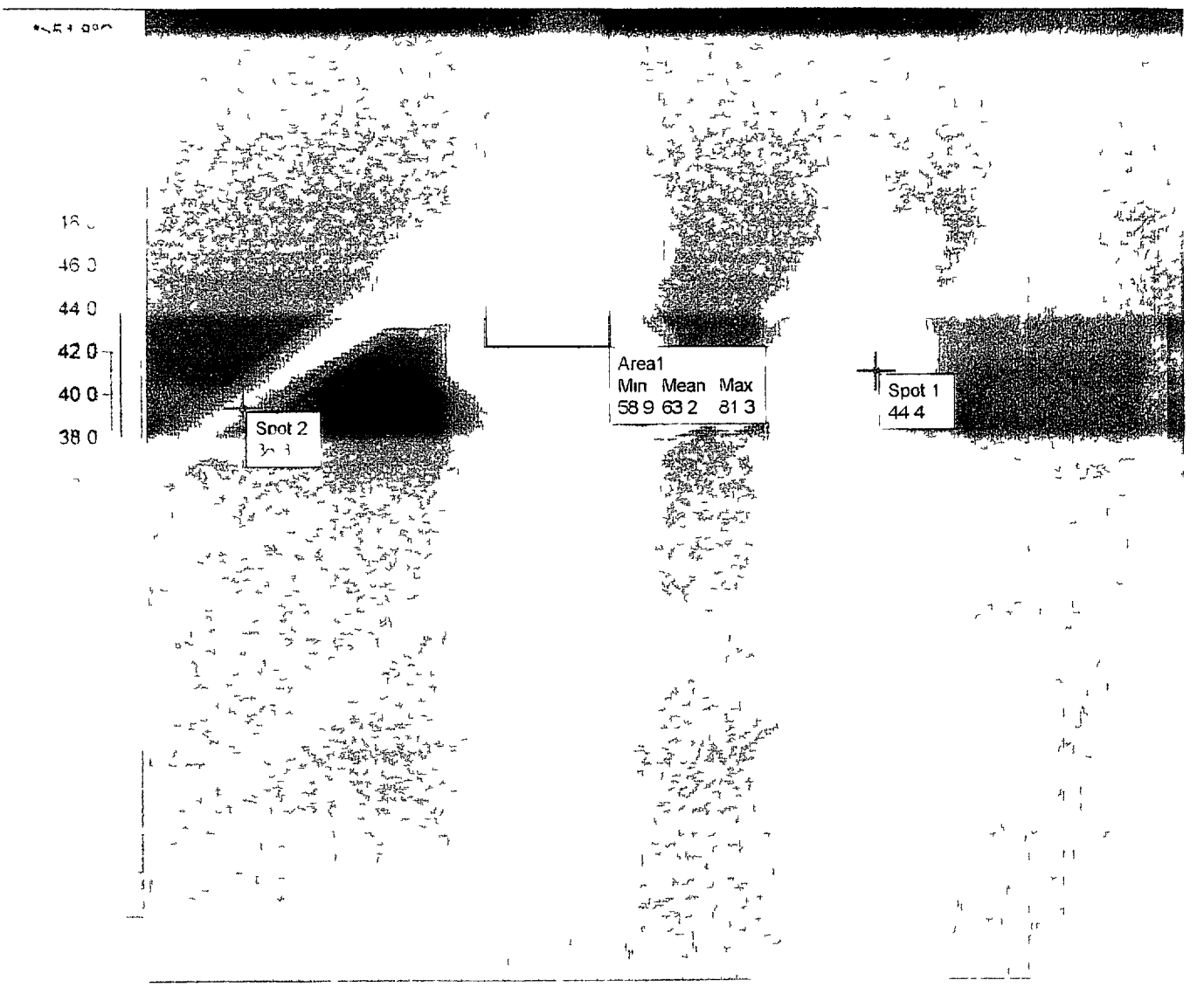
159

MOCB of 33KV D-2 132/33 KV T-2t/F

D10 TIF



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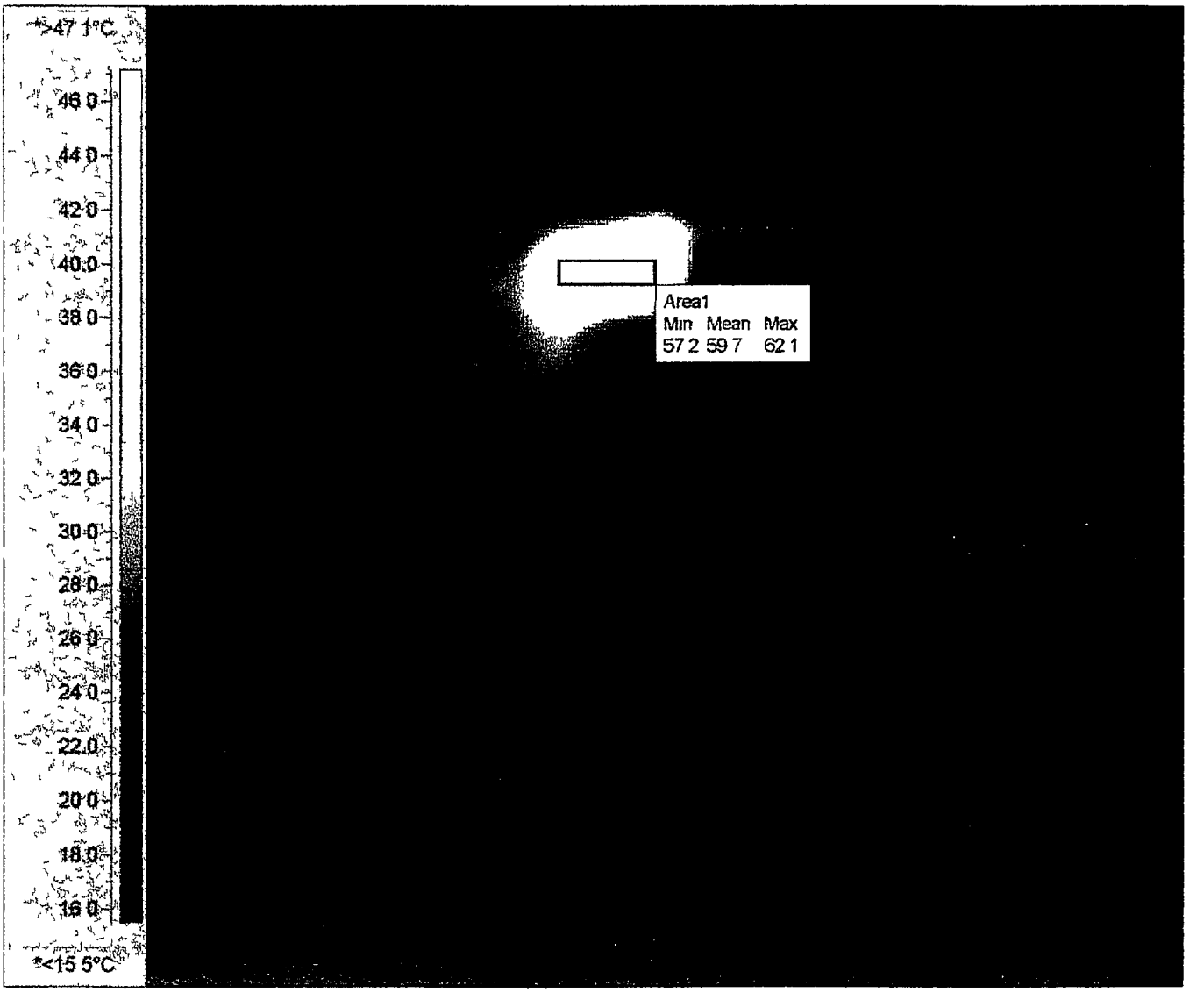
NDRI breaker clamp ~~red~~ hot

E06 TIF



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PN-ACF-475

FINAL REPORT

HVPNL
SYSTEM EFFICIENCY IMPROVEMENT TRAINING PROJECT

June 1998 – February 1999

A USAID- EMCAT
REGULATORY REFORMS & RESTRUCTURING PROJECT

Volume II

PREPARED BY THE

IRG INTERNATIONAL RESOURCES GROUP

INDIA

NEW DELHI, INDIA
FEBRUARY 1999

162

NILOKHERI SWITCHYARD

Nilokeri Deficiencies

Mimic bus does not depict physcial layout

No blue light for the spring charged indication

CT ratio on 132 kv not indicated

Ammeter reading load while breaker is open Ammeter non-functional

No breaker on 132 kV incoming line

Surge counters not working on surge arresters

Improper crushed rock protection

Contacts on disconnect switch rusted so semaphores are not working

Damaged or missing covers on trenches

Improper structure ground on isolators

Top of rod gap is missing on isolators

Control cable to disconnect switch is not in conduit Exposed PVC Cables

Transformer containment area is not adequate No oil containment

11 kV cables are not buried and are laying on the surface of the switchyard

Some cap units are out of service due to unreplaced fuses

No L/A on capacitor bank

Incorrect bolts on connectors and so bolts are corroded

Improper fusing on ground mounted cap banks

Tape on 11 kV jumpers serves no purpose

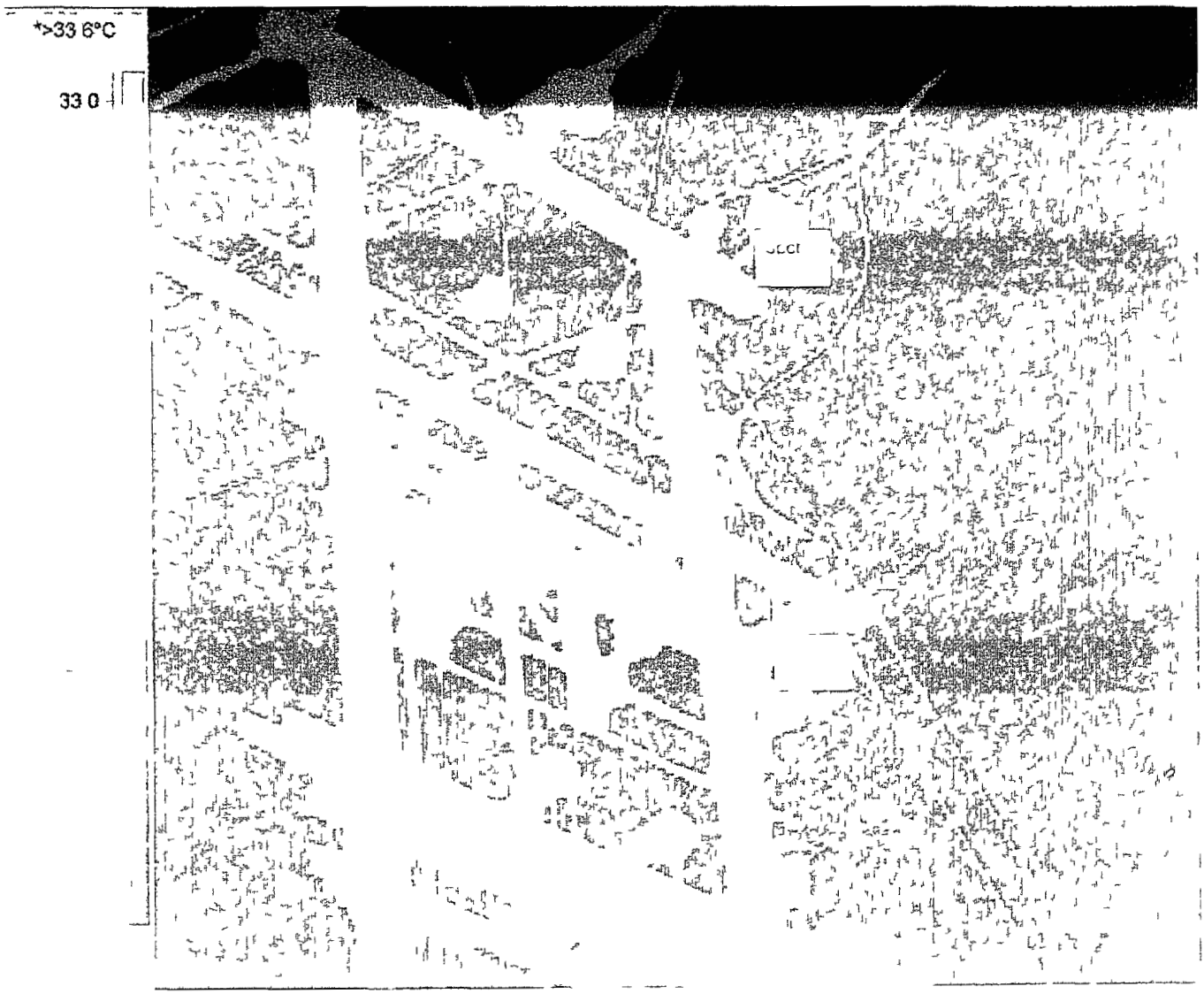
No fuses on battery cables

Mimic bus diagram shows (2) -132 kV busses whereas there is only one

Function of indicating lights should be identified with nameplates

132KV Substation,NILOKHERIGOS H-Pole250kva PolytecTfr

F15 TIF



inframetrics TherMonitor 95 11/24/98 10 12 26 PM

165

132KV Substation,NILOKHERI,G O Switch Jumper(N A C Tfr)

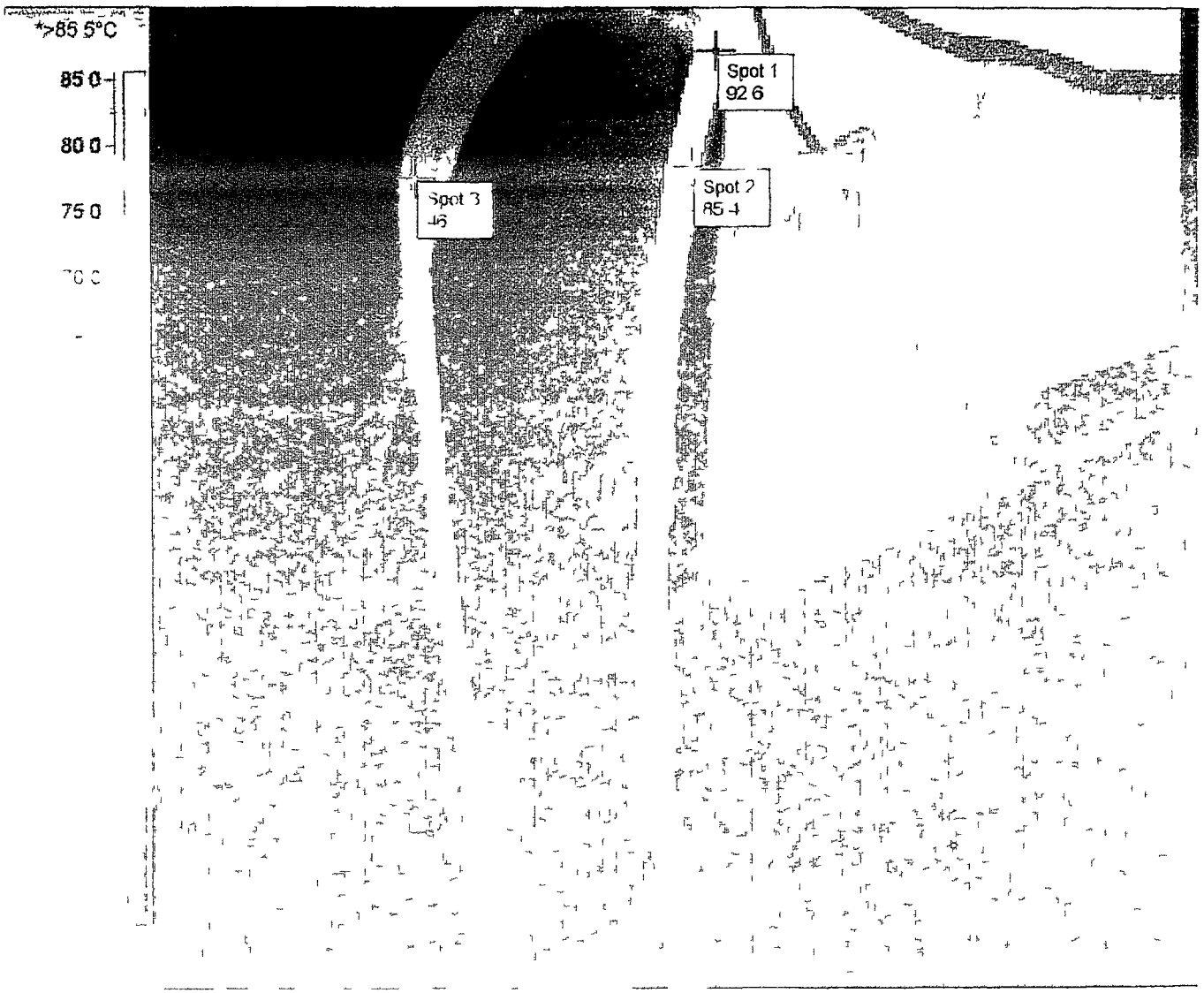
F10 TIF

inframetrics TherMonitor 95 11/24/98 8 51 59 PM

1 of

132KV SubstationNILOKHERI,LEAD FROM T/fr to LT Fuse Unit

F08 TIF



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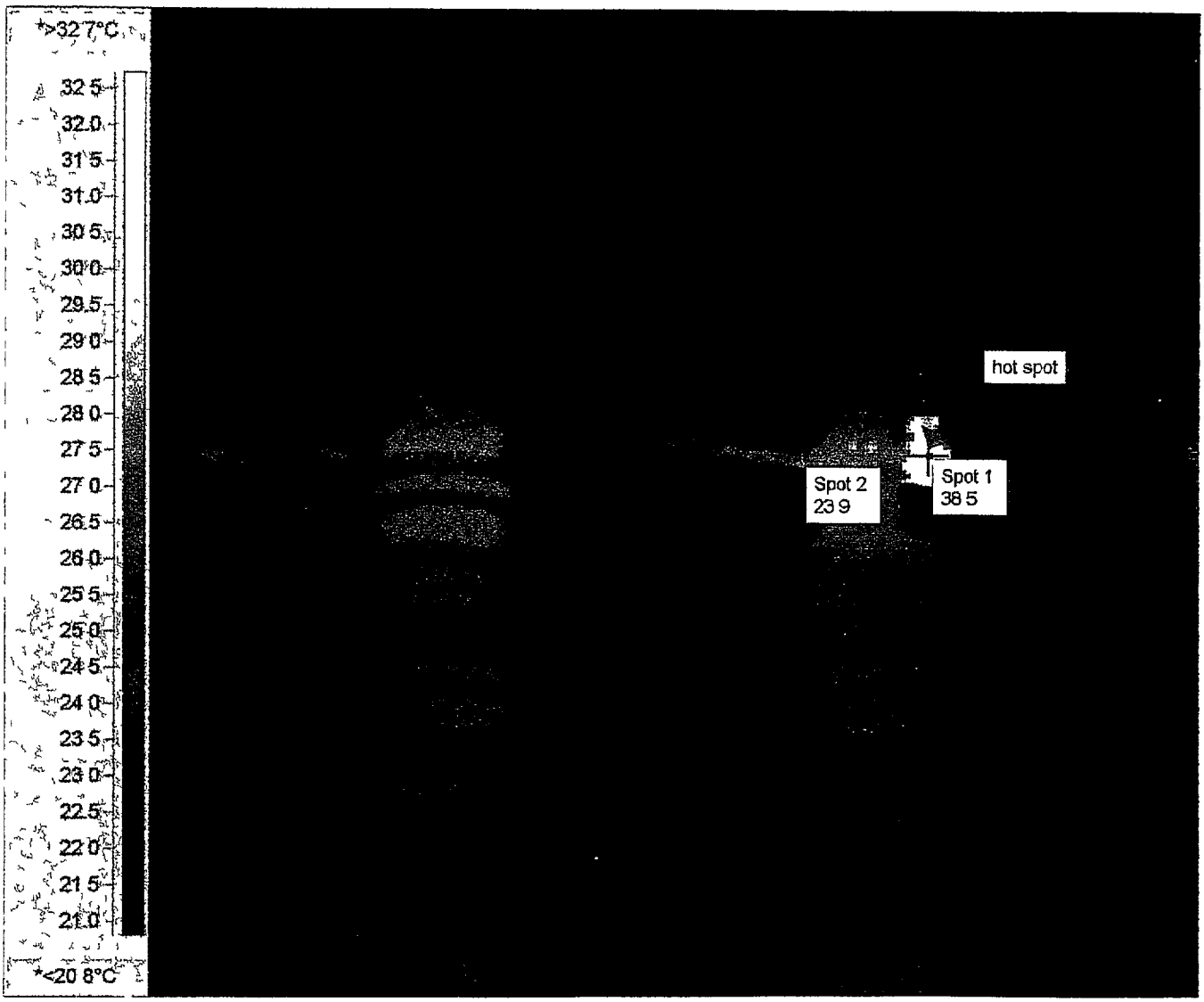
167

132KV Substation,NILOKHERI132KV Isolator controllingT/Fr-T2

F06 TIF



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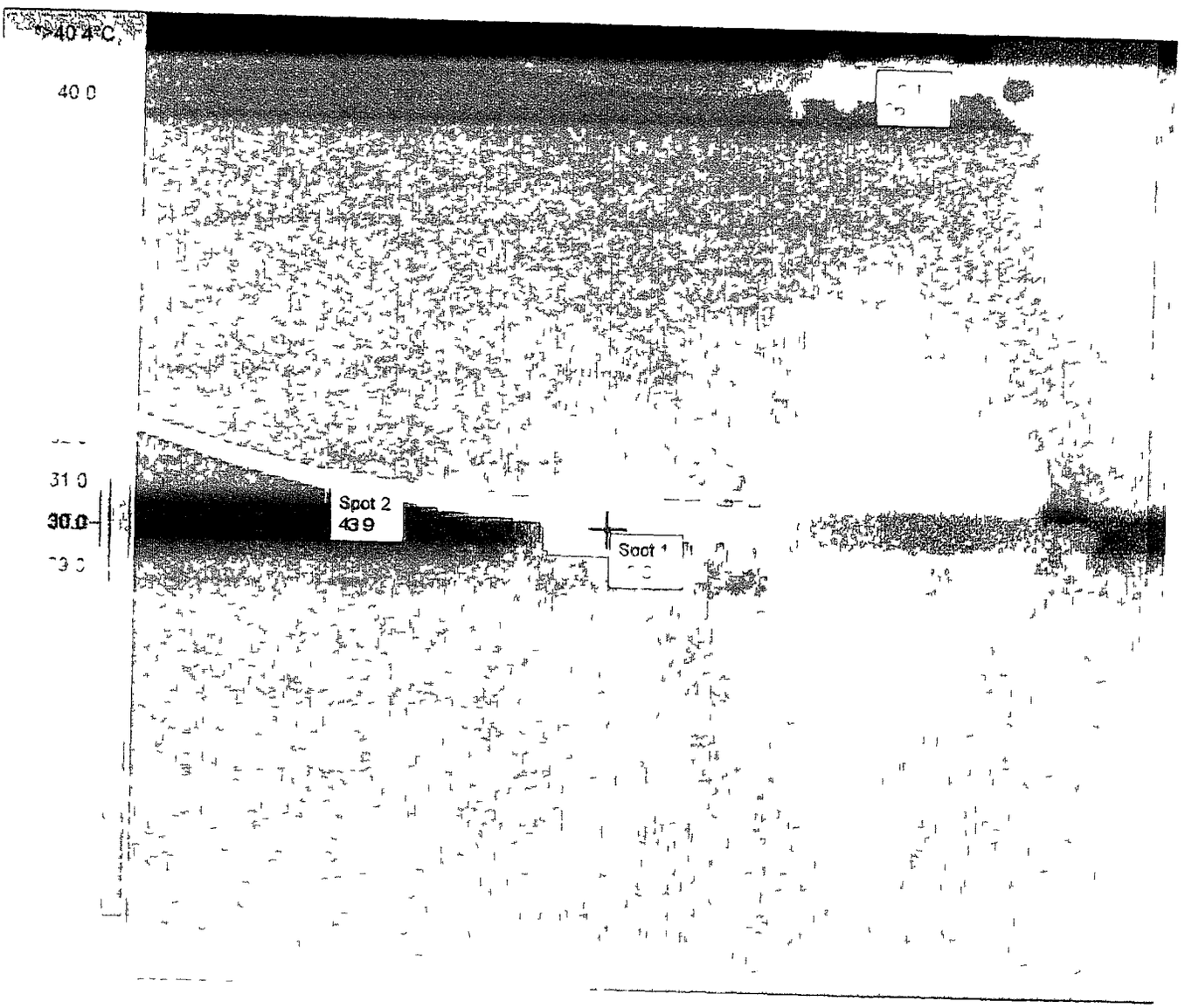
132 KV Substation,NILOKHERI,33 KV ISOLATOR CONTROLLING 33 KV

F04 TIF



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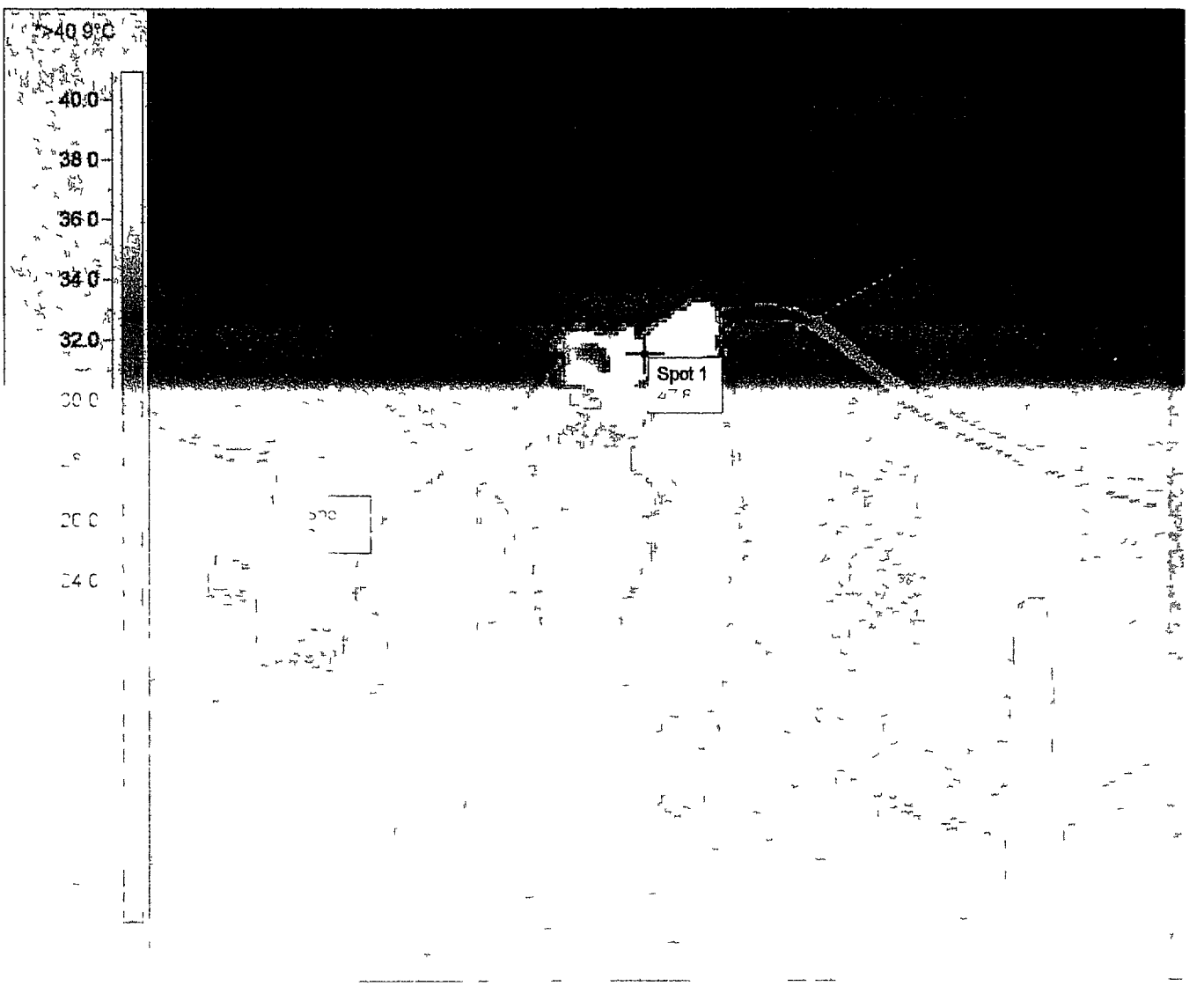
132 KV Substation,NILOKHERI,33 KV ~~MAIN~~ ISOLATOR CONTROLLING 33 KV

F02 TIF



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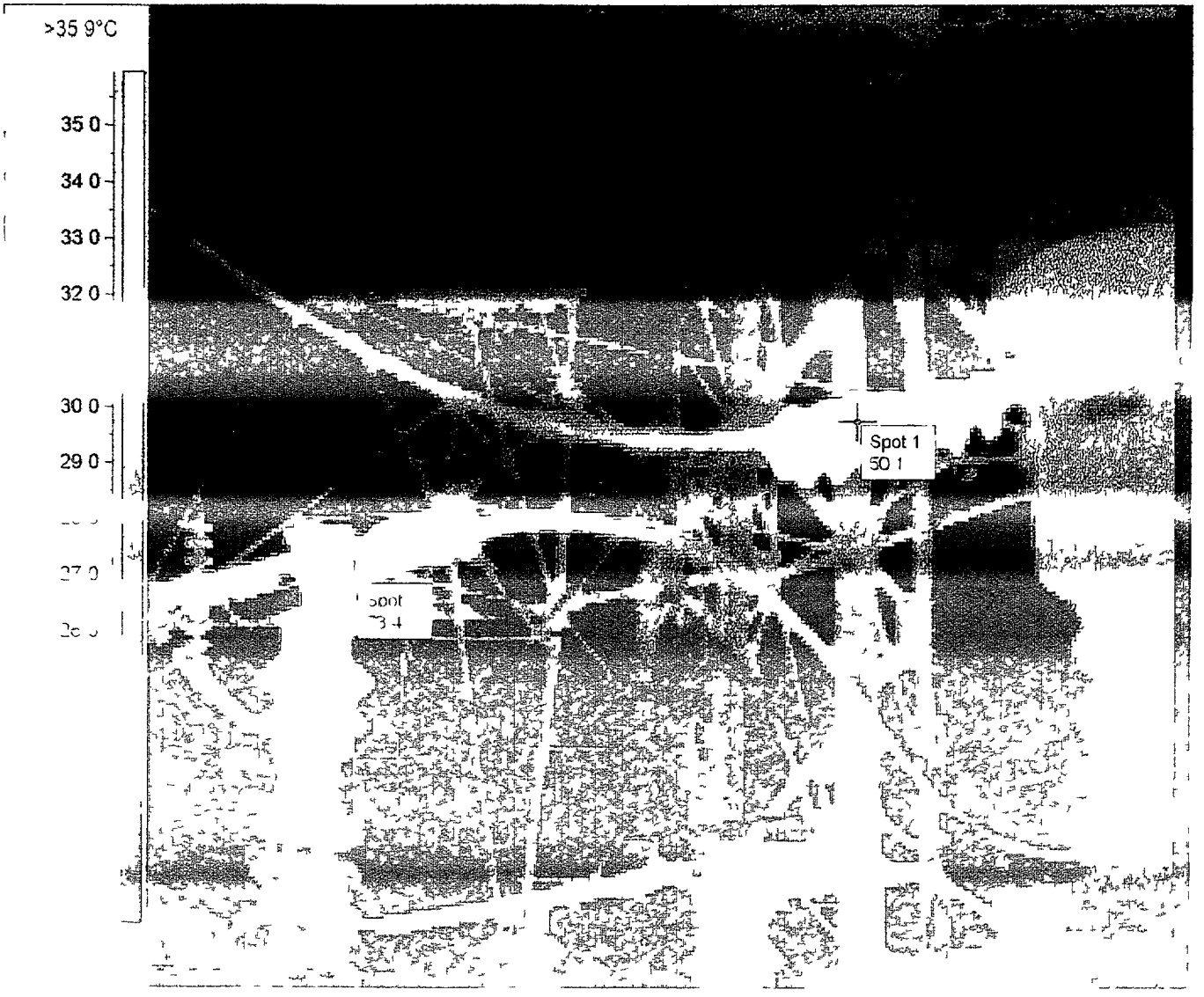
170

132 kv Substation,Nilokheri

F03 TIF



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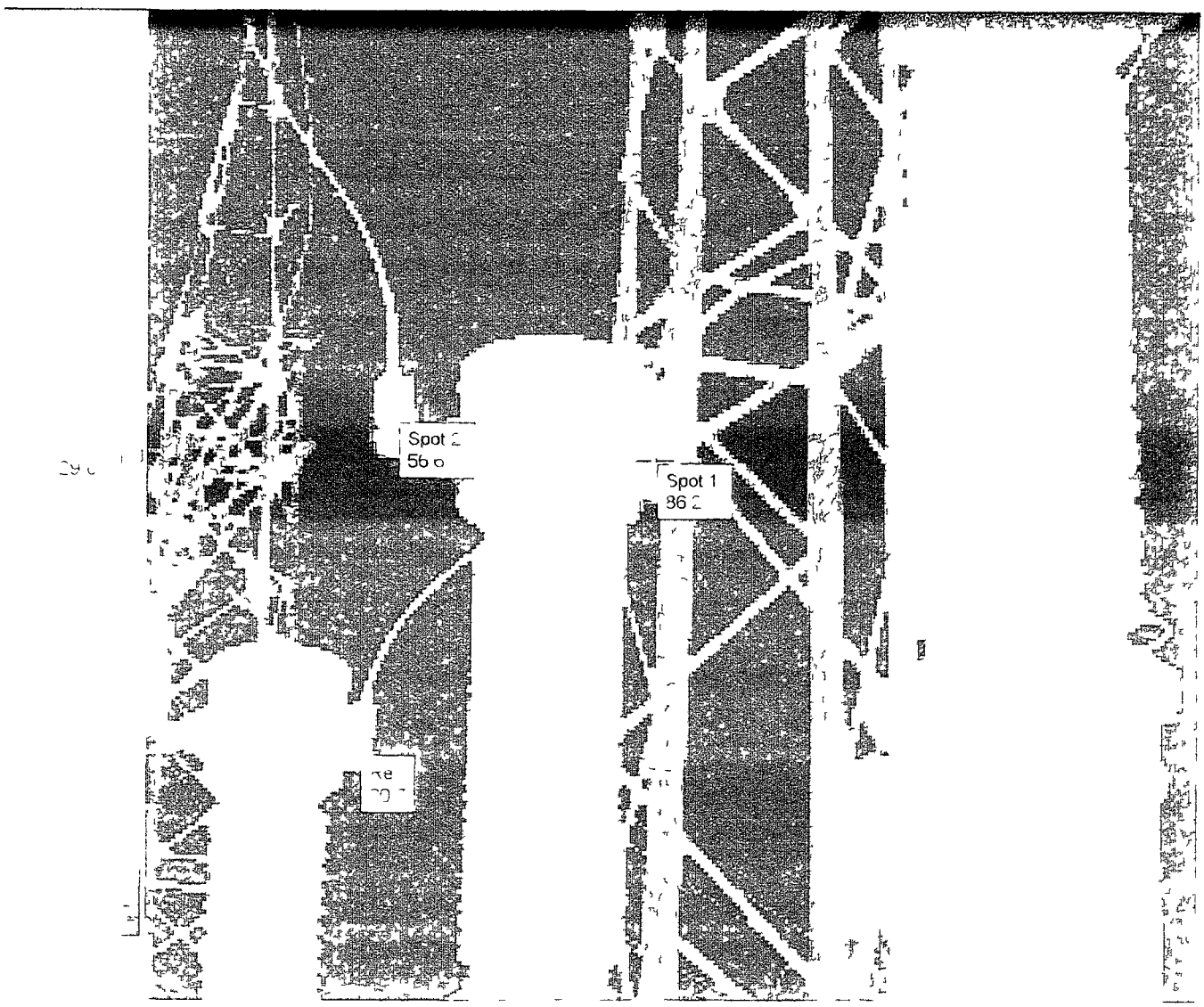
132 KV Yellow Phase CT of 132 KV Substation,Nilokheri

F05 TIF



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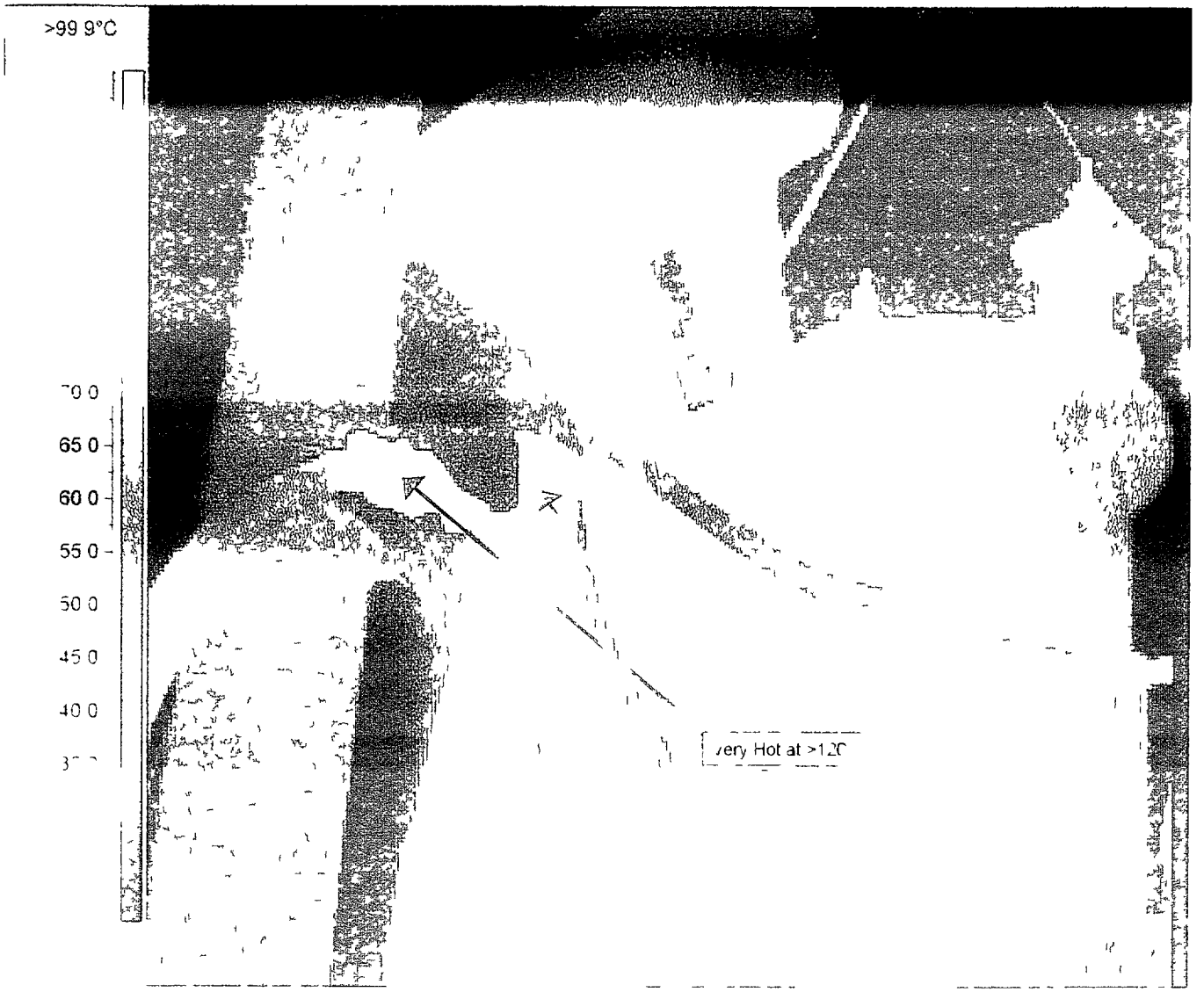
100 KVA N A C T/FR,NILOKHERI

F07 TIF



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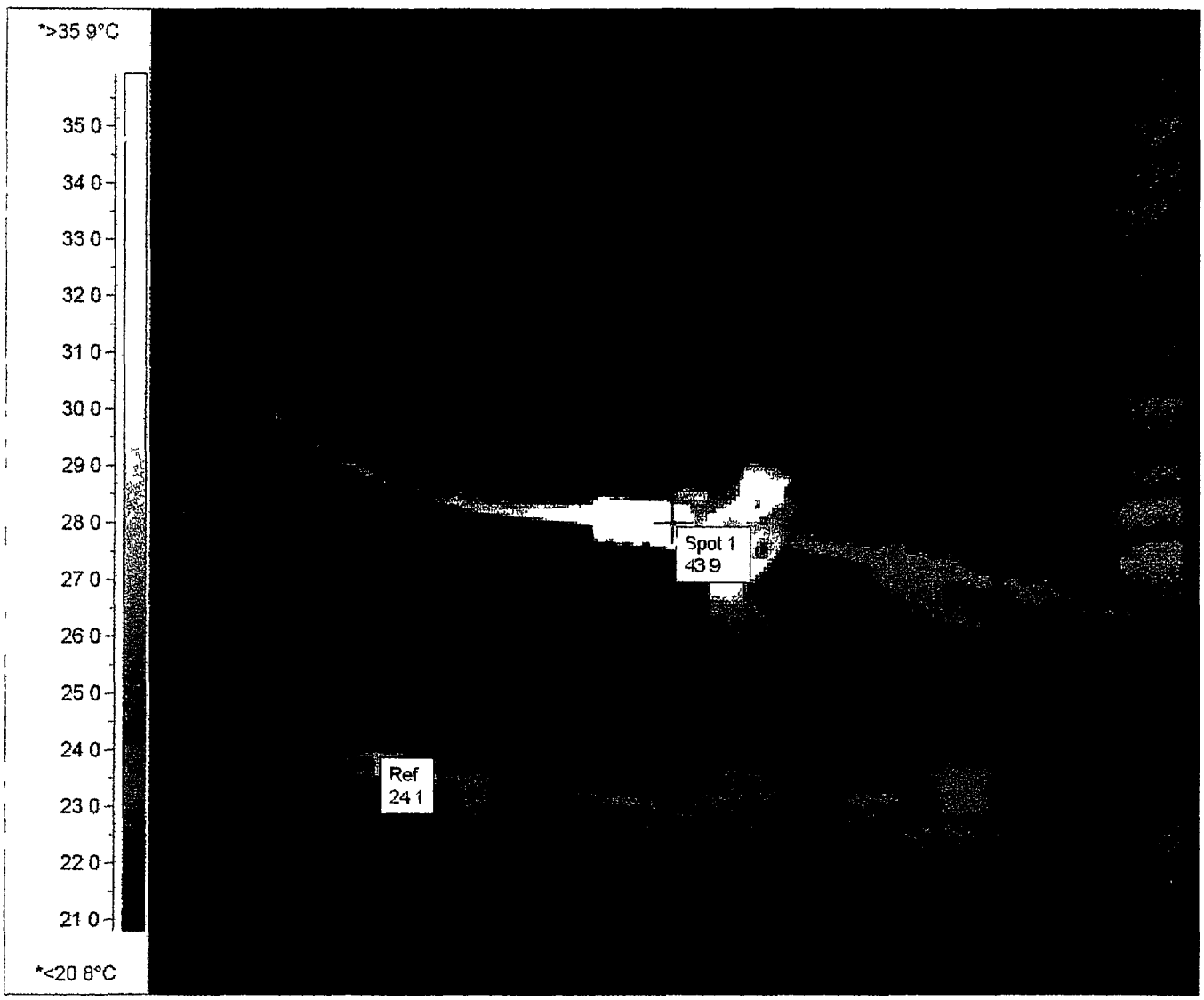
132 KV Substation,Nilokheri,33 KV main Isolator

F01 TIF



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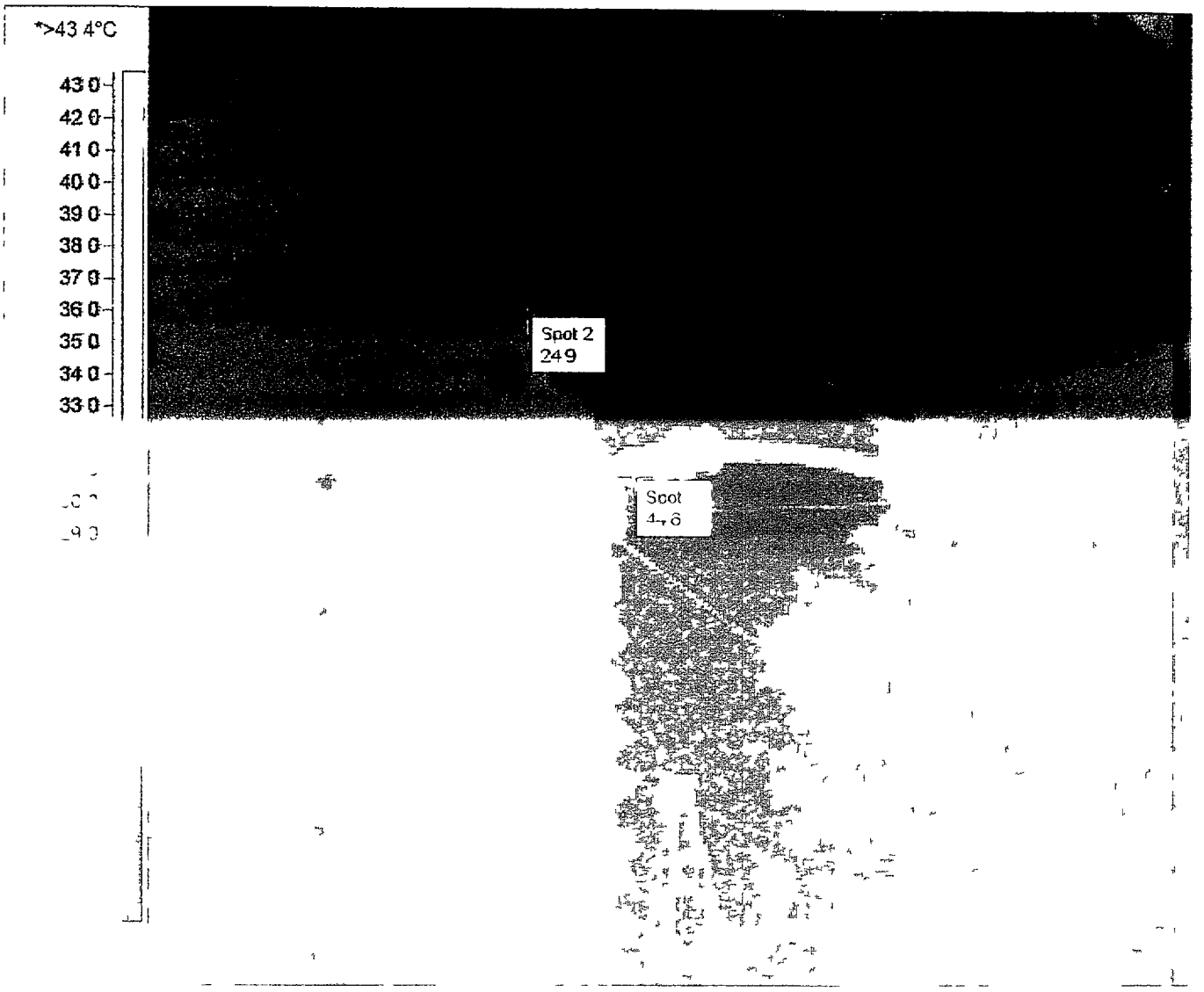
132KV Substation,NILOKHERI,33kv Main(D1) TO M O C B

E16 TIF



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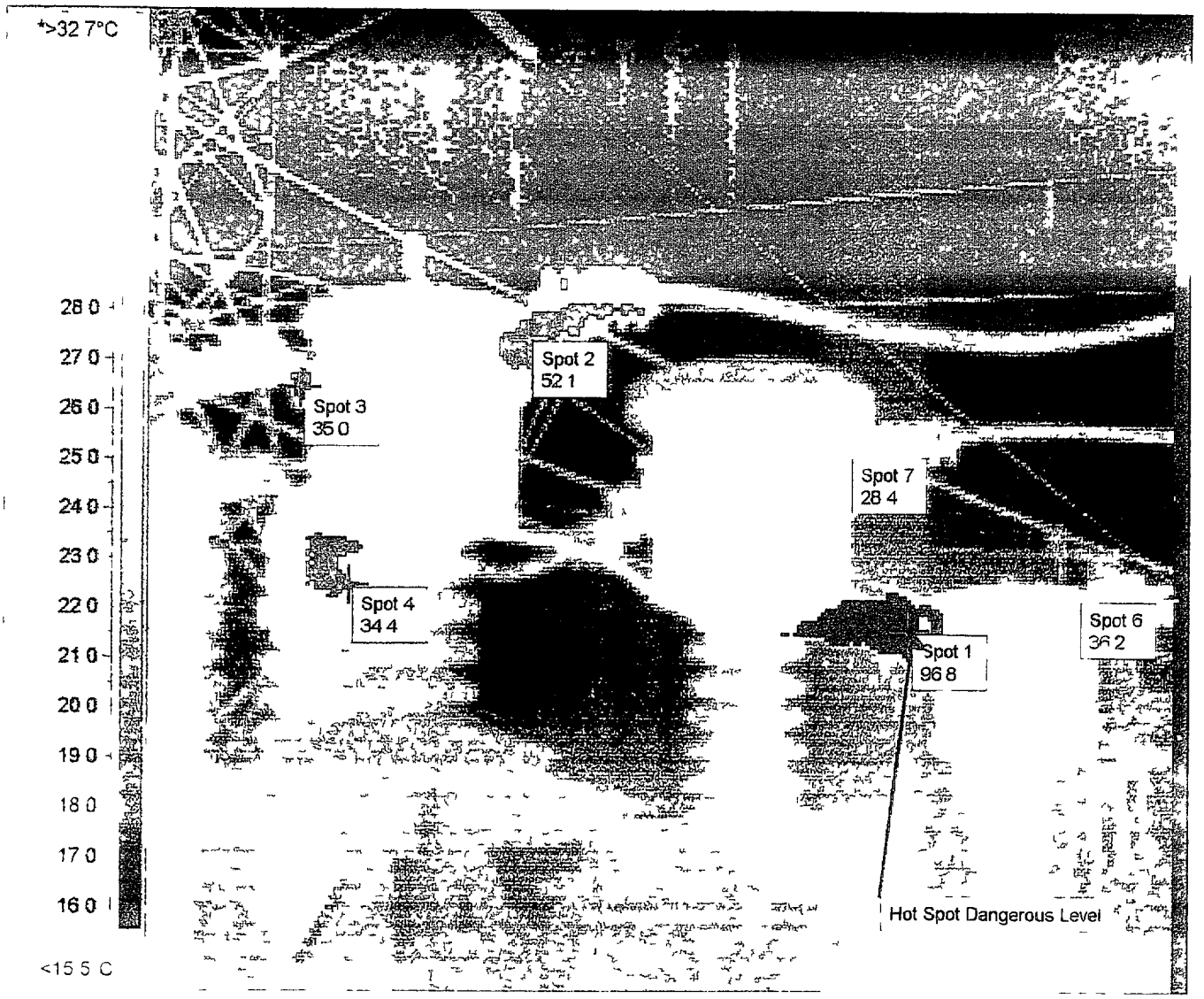
175

132 KV Substation,NILOKHERI, Isolator-33KV to33KV C T,Jumper

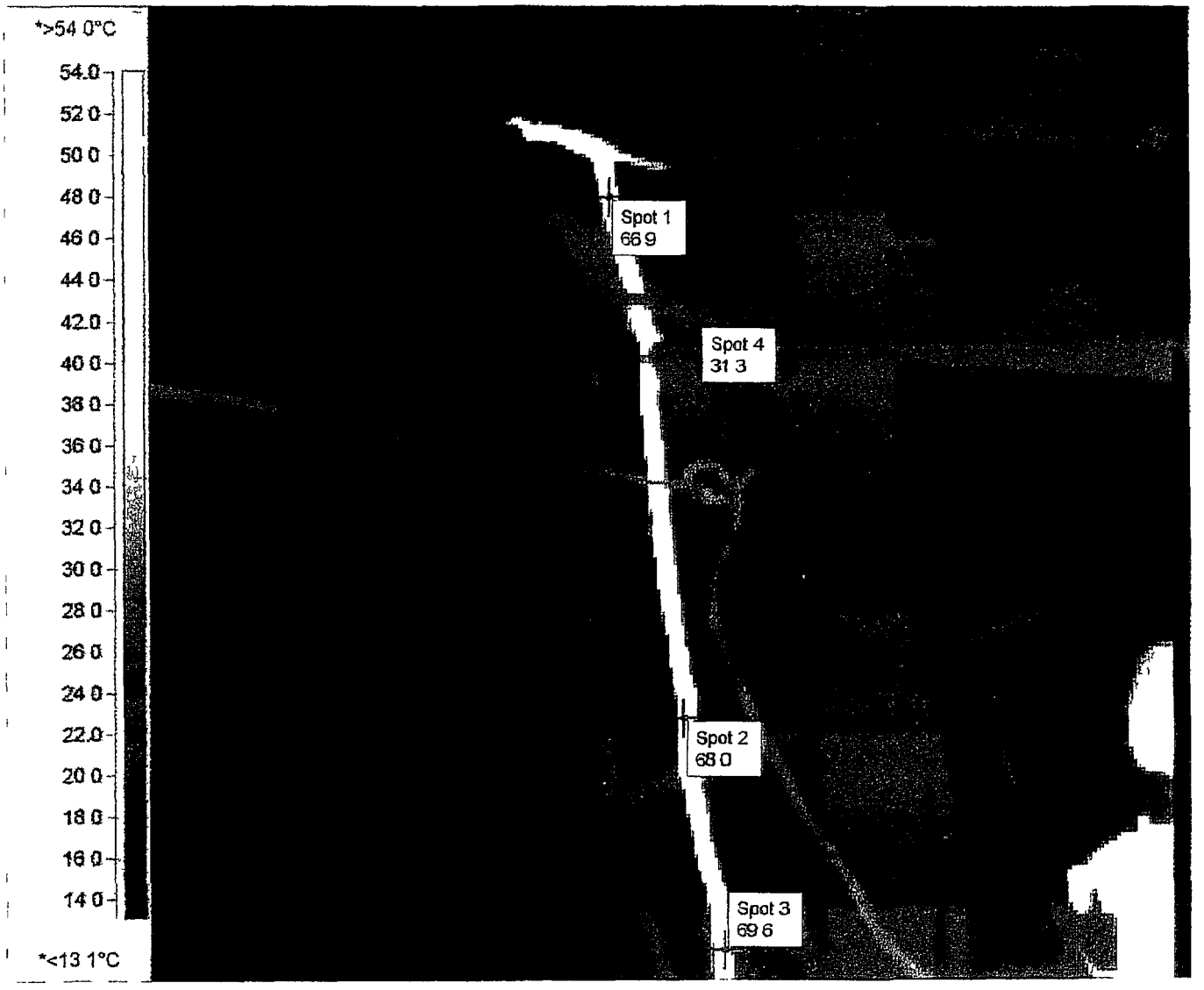
E15 TIF



inframetrics TherMonitor 95 11/24/98 6 13 45 PM

132KV Substation,NILOKHERI,LEAD FROM T/fr to LT Fuse Unit

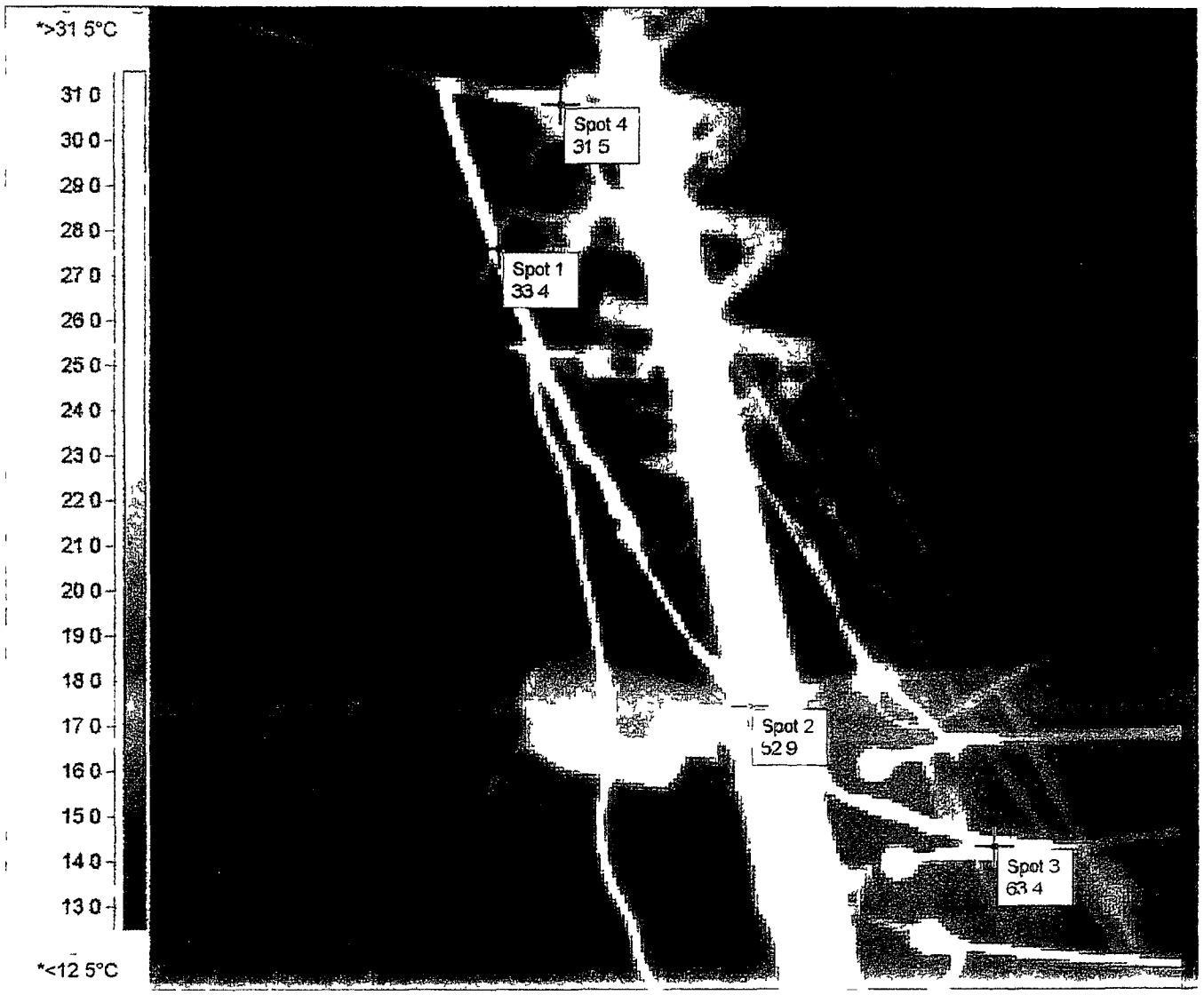
F09 TIF



inframetrics TherMonitor 95 11/24/98 8 59 08 PM

132KV Substation,NILOKHERI,COMMON POLE(N A C Tfr)

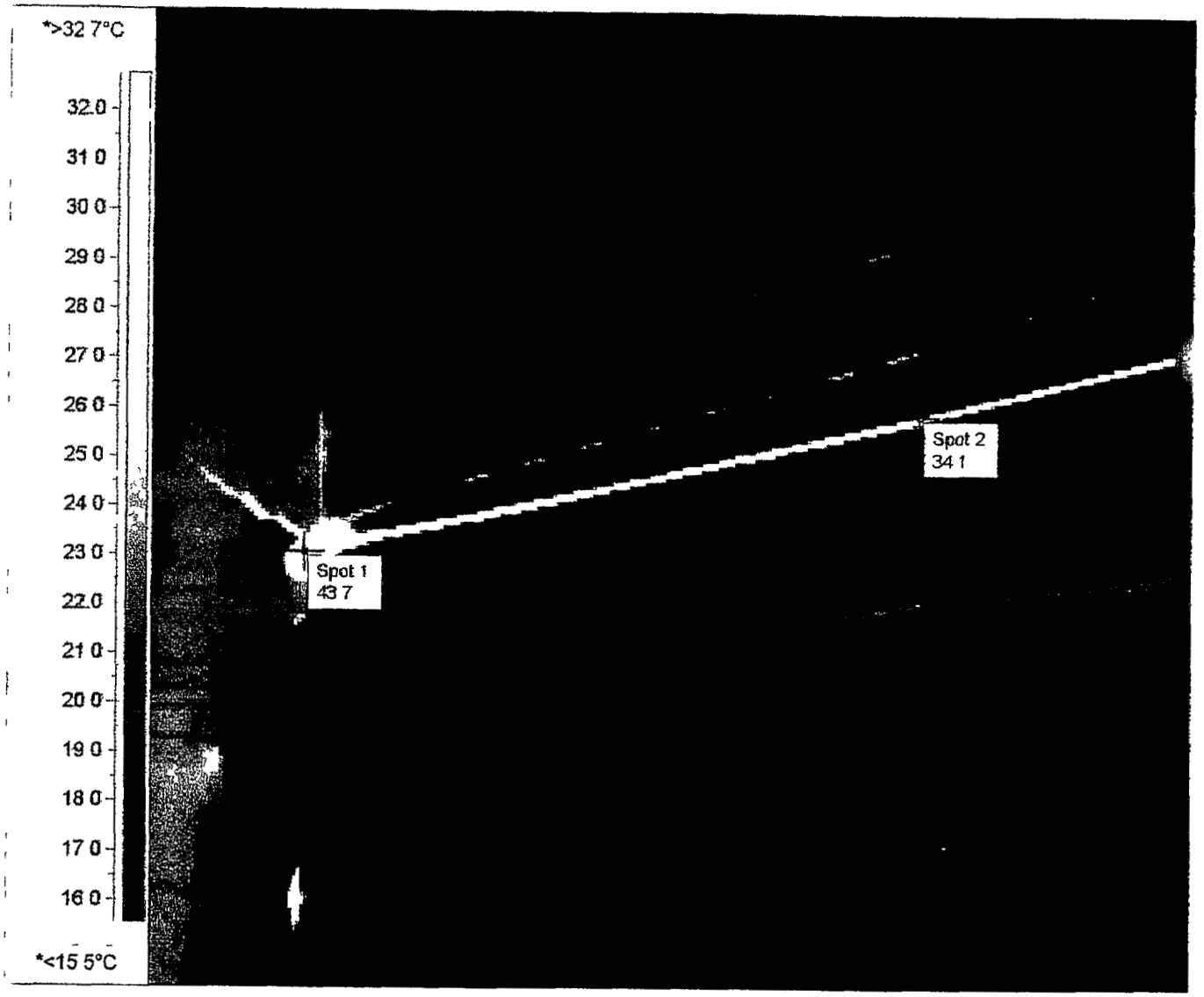
F11 TIF



inframetrics TherMonitor 95 11/24/98 9 07 14 PM

132KV Substation,NILOKHERI,Common Pole(200kvaAryaSmal)toLTFus

F12 TIF

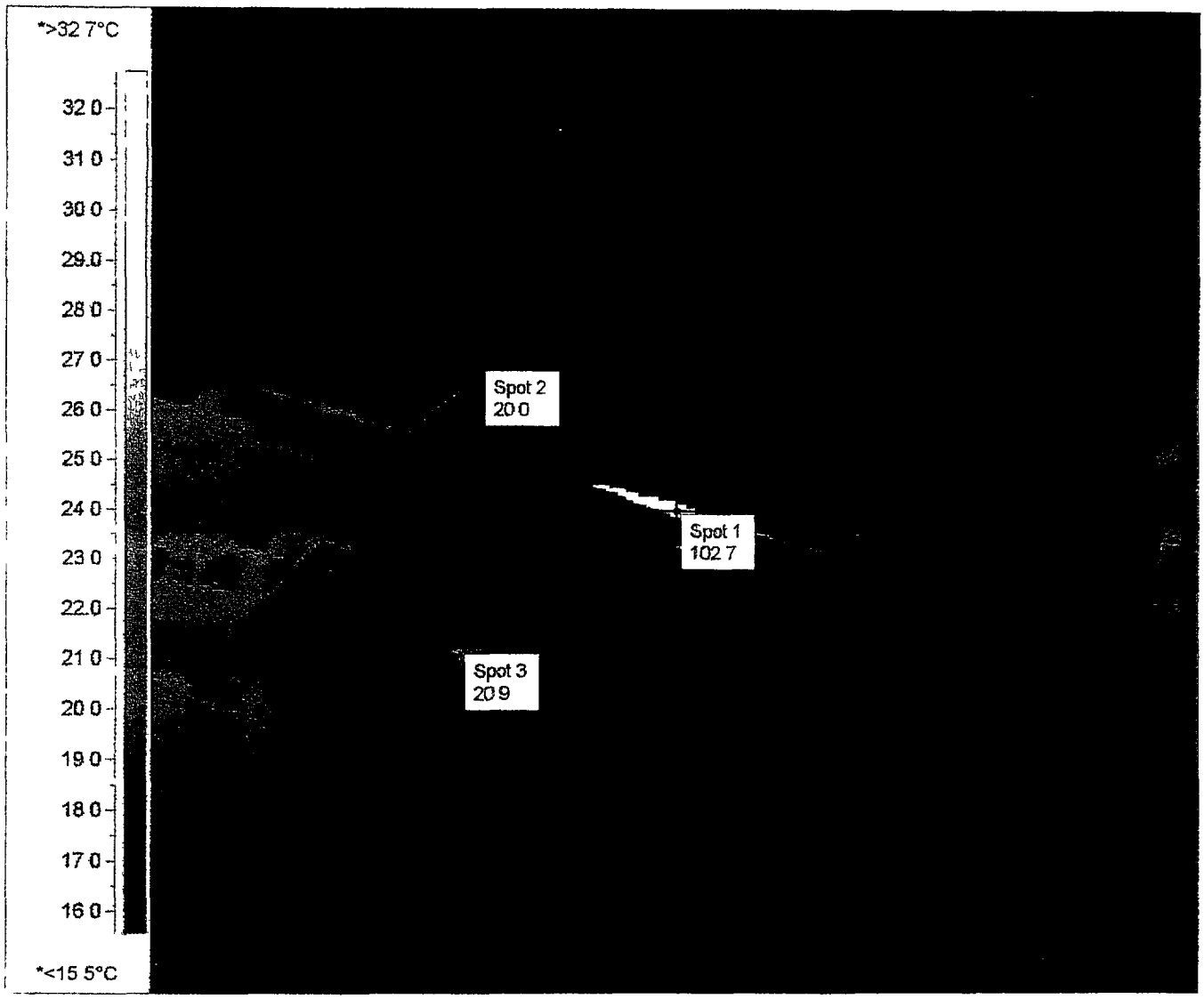


inframetrics TherMonitor 95 11/24/98 9 20 02 PM

132KV Substation,NILOKHERI,Common Pole(AyaSmaj Tfr)Outgoing

L T Conductor

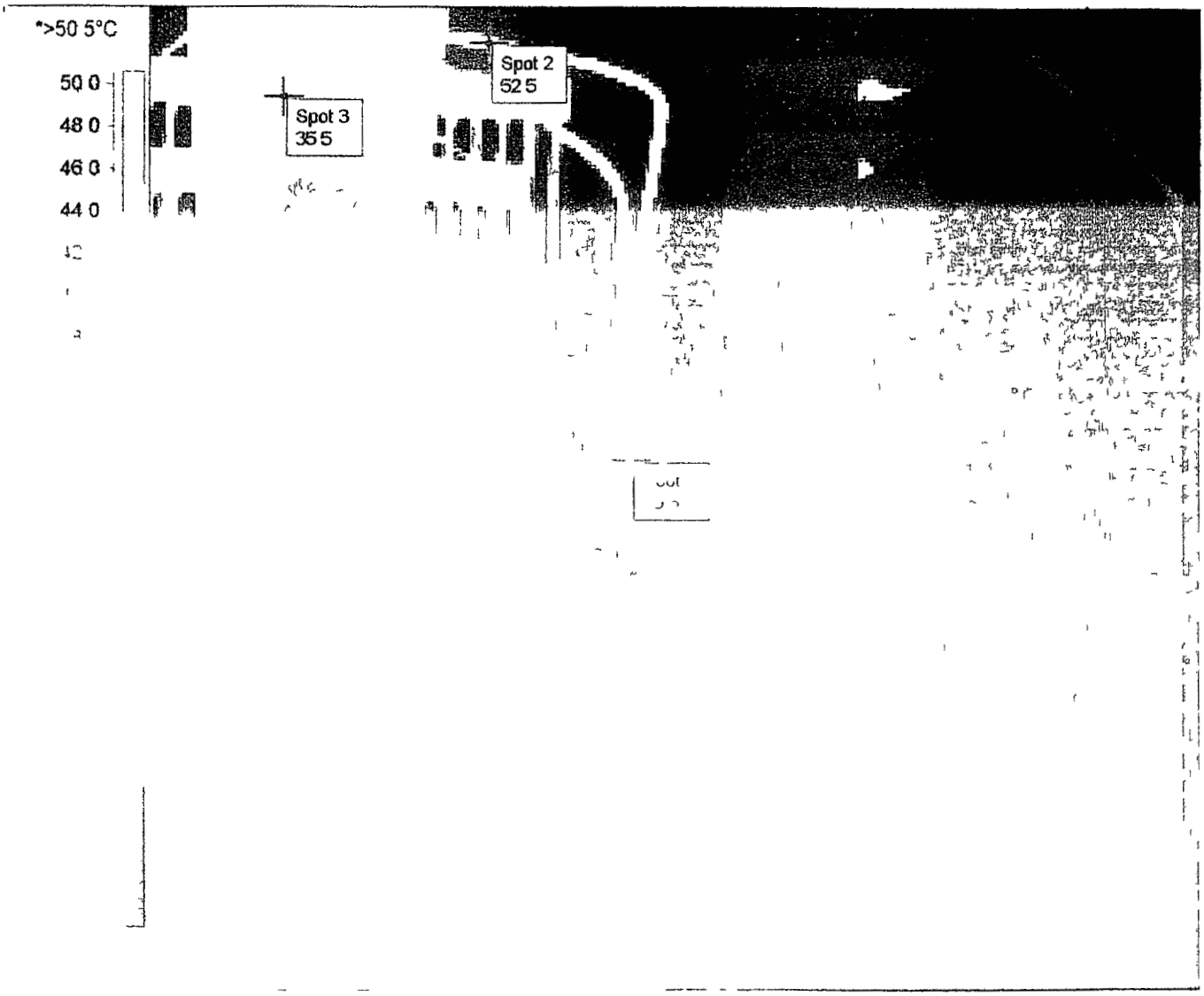
F13 TIF



inframetrics TherMonitor 95 11/24/98 9 24 39 PM

132KV Substation,NILOKHERI,AyaSmaj Tfr L T Jumper

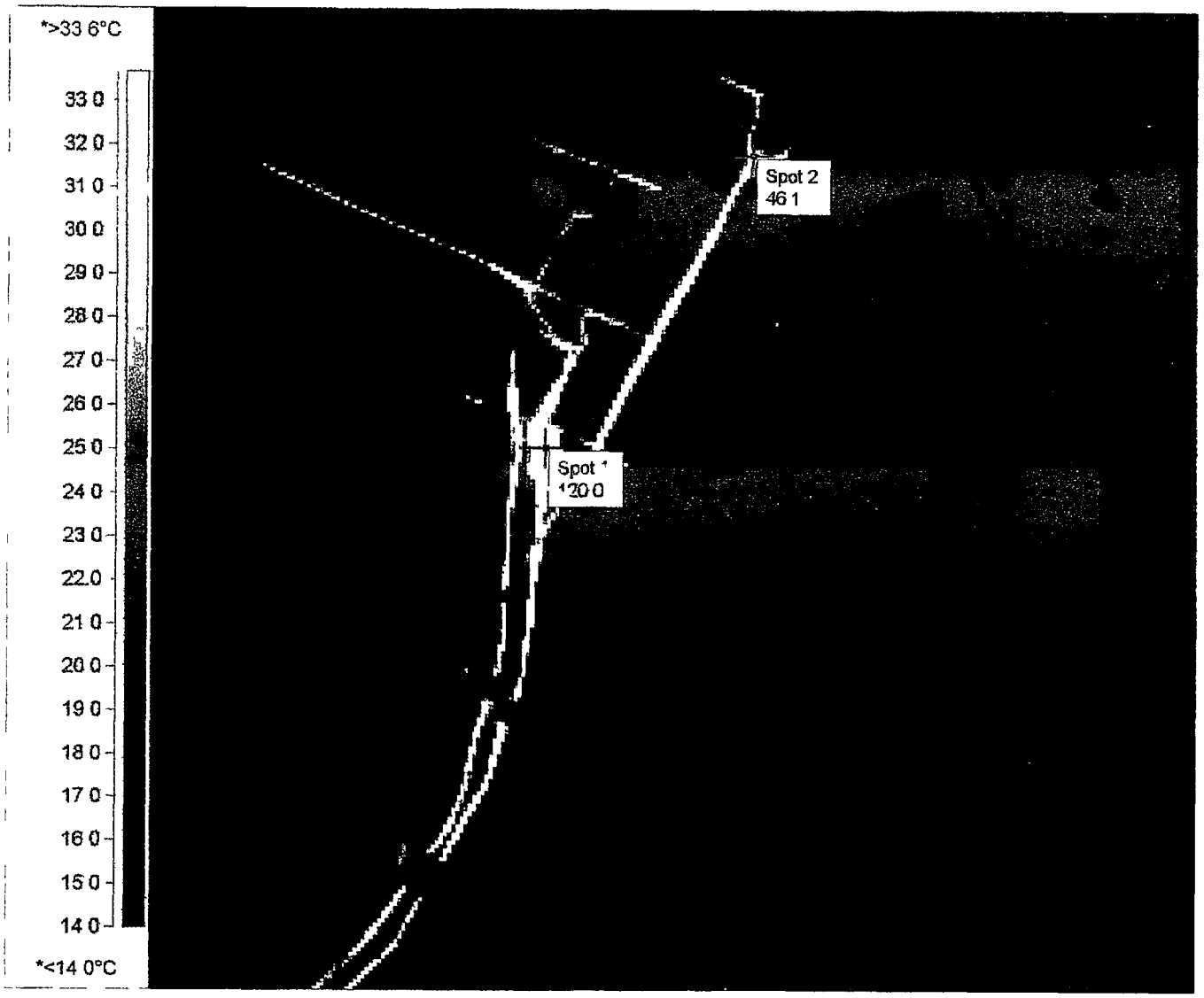
F14 TIF



inframetrics TherMonitor 95 11/24/98 9 31 03 PM

132KV Substation,NILOKHERI,L T Cable to commo pole(poltec)

F16 TIF

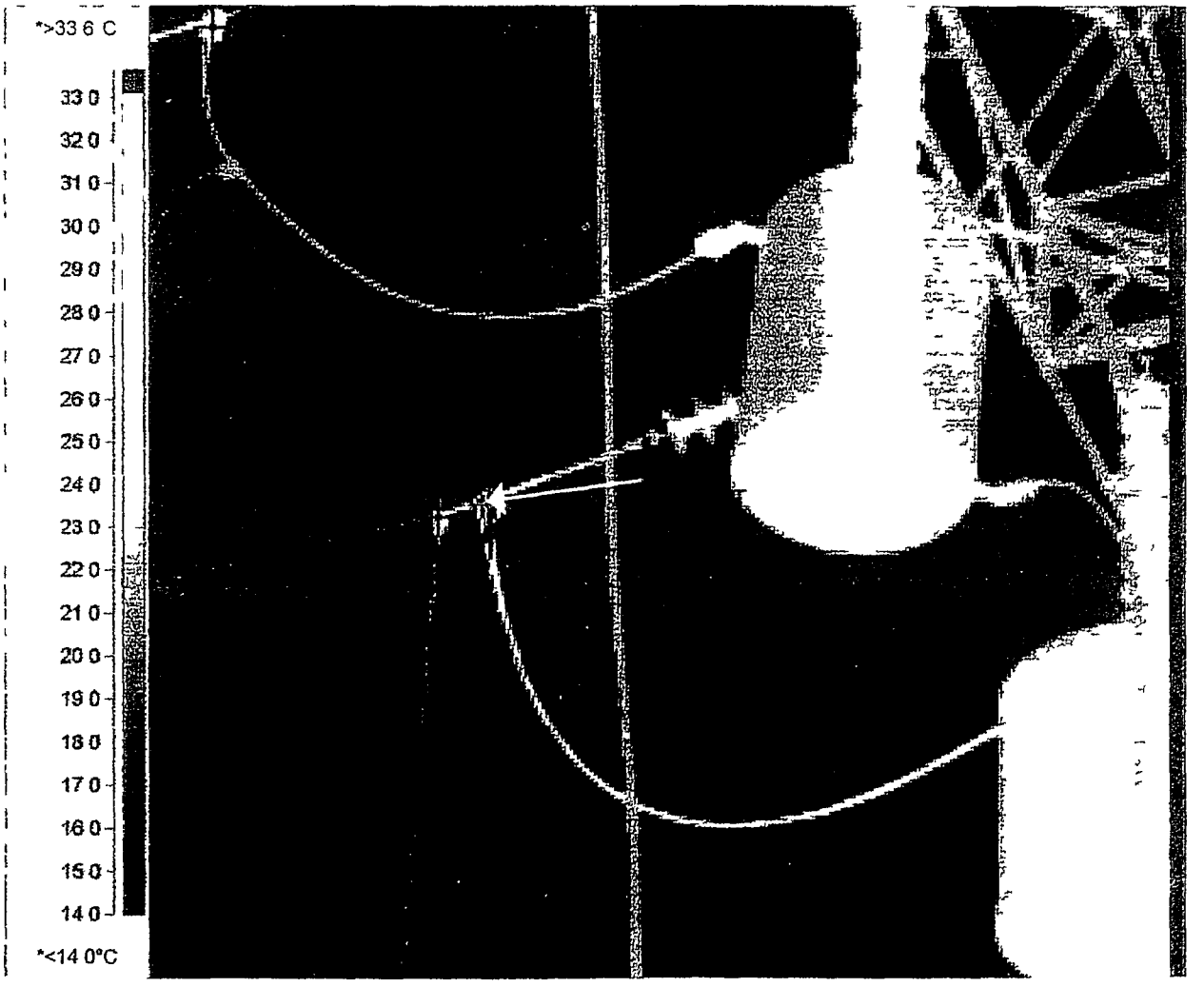


inframetrics TherMonitor 95 11/24/98 10 17 10 PM

132 KV Substation, NILOKHERI Thermal Image on 18/11/98

(132 KV Main Blue phase Jumper)

E12 TIF

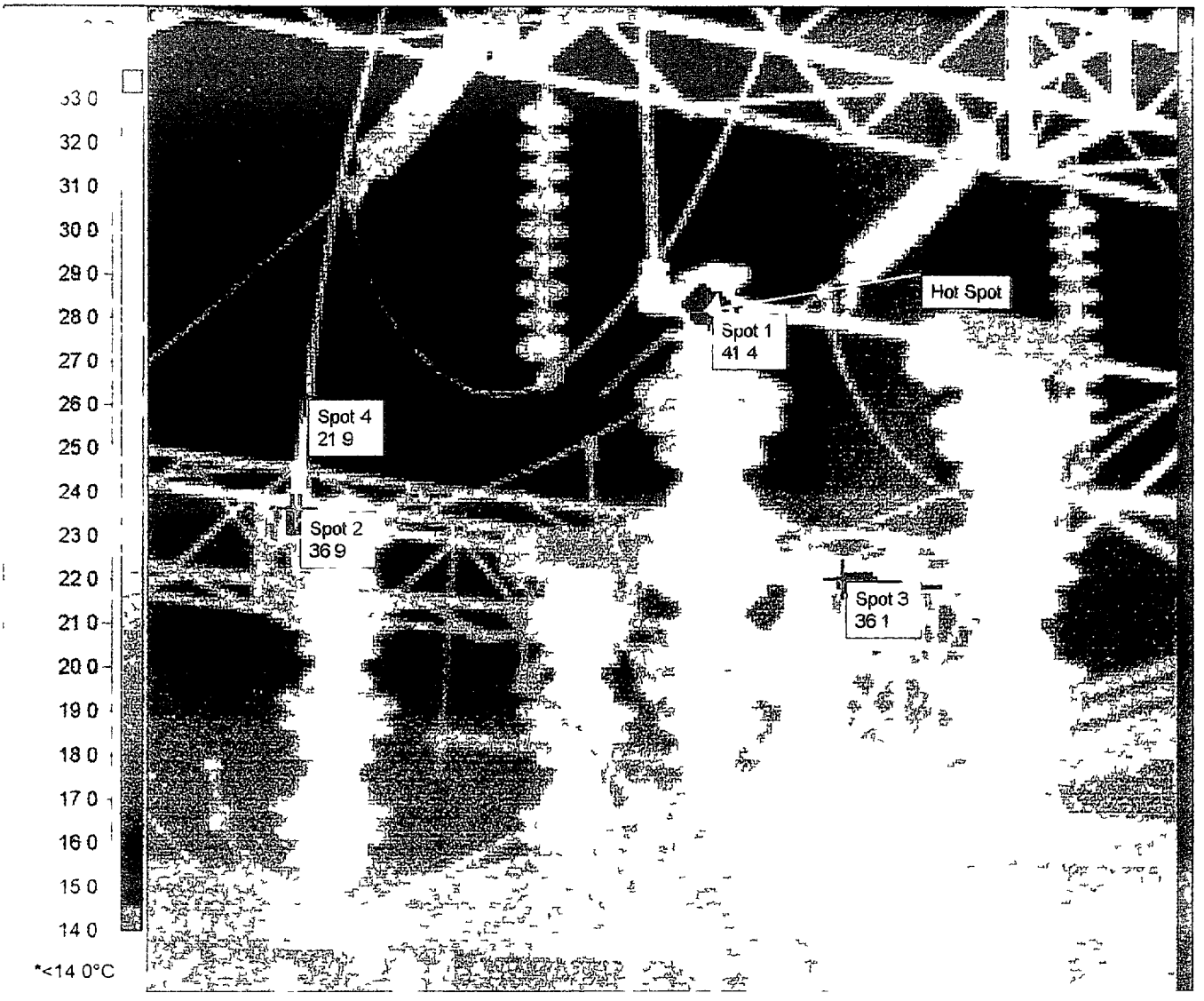


inframetrics TherMonitor 95 11/24/98 4 27 57 PM

132 KV Substation,NILOKHERI,Thermal Image Scan

(Main 132 KV Isolator)

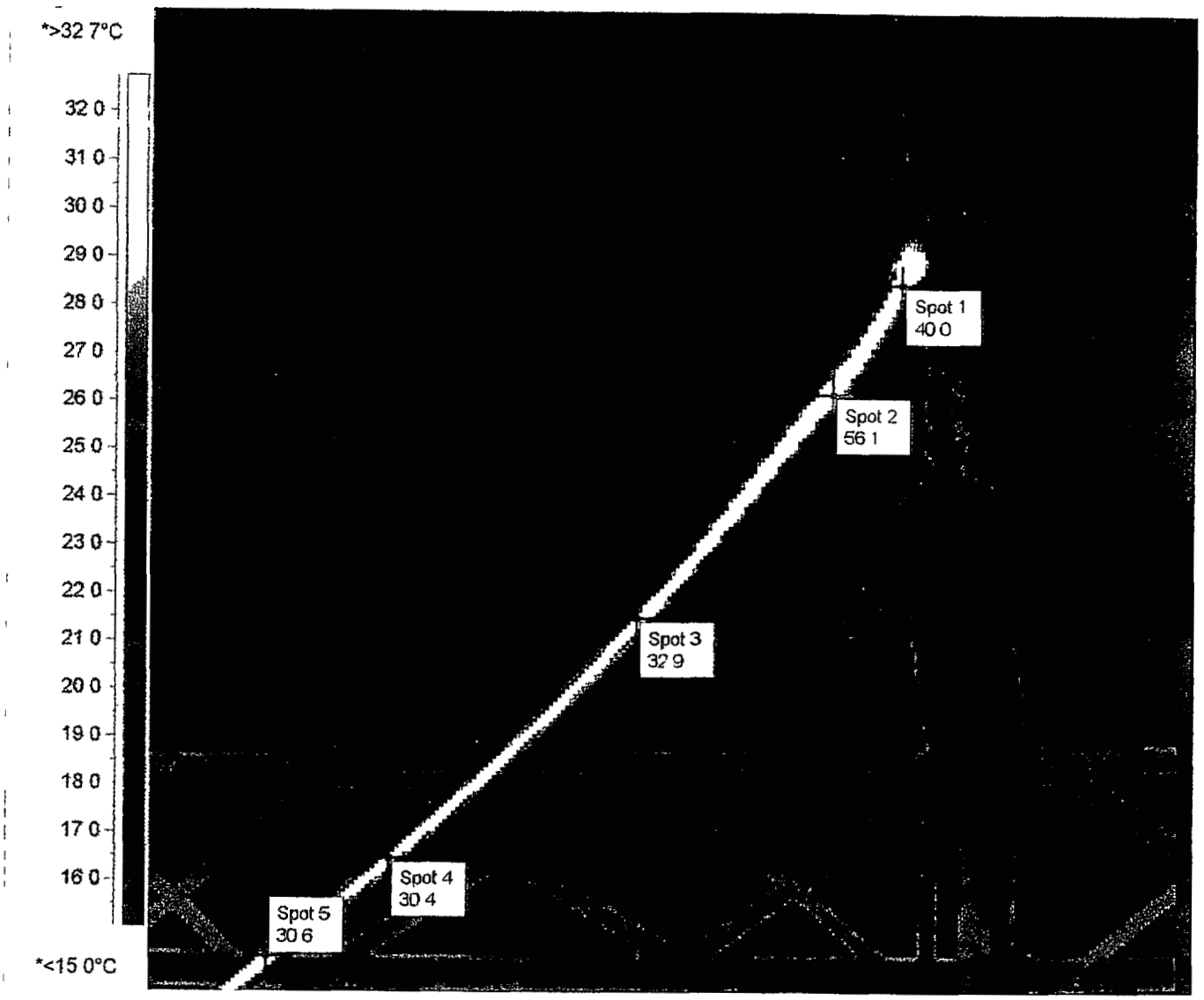
E13 TIF



inframetrics TherMonitor 95 11/24/98 5 16 06 PM

132 KV Substation,NILOKHERI, Isolator-132KV to 132KV Jumper

E14 TIF



inframetrics TherMonitor 95 11/24/98 5 43 04 PM

MADHUBAN SWITCHYARD

Madhuban Substation Deficiencies

Corroded ground on surge arresters

Shield wire coverage not adequate

Ground switch disconnects – auxiliary contacts corroded so semaphores don't work Also, linkage is broken

Openings in control box are not sealed

Improper crushed rock protection

Control panel on 132 kv – door has missing gaskets and rain has entered, although terminal are not corroded All connectors are spade type while ring type is needed Heater is corroded

One outdoor cabinet is rusted closed and could not be opened

No one knows if the oil level in the power transformer conservator tank is proper or not No manuals are available

Oil catch basin is not adequate

Bucholz relay leaking oil at gaskets Oil leaking into the breather on power transformer

Cover plate is missing from opening in control panel on power transformer SSE replaced it during the inspection

Oil leak on power transformer

Nameplate on power transformer not readable

2 of 3 connectors on 33 kV have corroded bolts and indicated hot spot on scans

Opened stranding on 33 kV jumpers

Covers missing on trench

Bending radius too tight on 33 kV jumper

33 kV breaker target is the wrong color

Poor stranding on 132/11 kV transformer jumpers – showed hot spot

Bulbs burnt out on many metal-clad circuit breaker panels

No fuses on battery cables

Ground fault on DC system Battery is totally discharged when charger is disconnected

11 kV breaker on Kamopura feeder shows "OFF" when breaker is closed

Bus coupler indicates ON when it is OPEN

Other breakers have similar problems

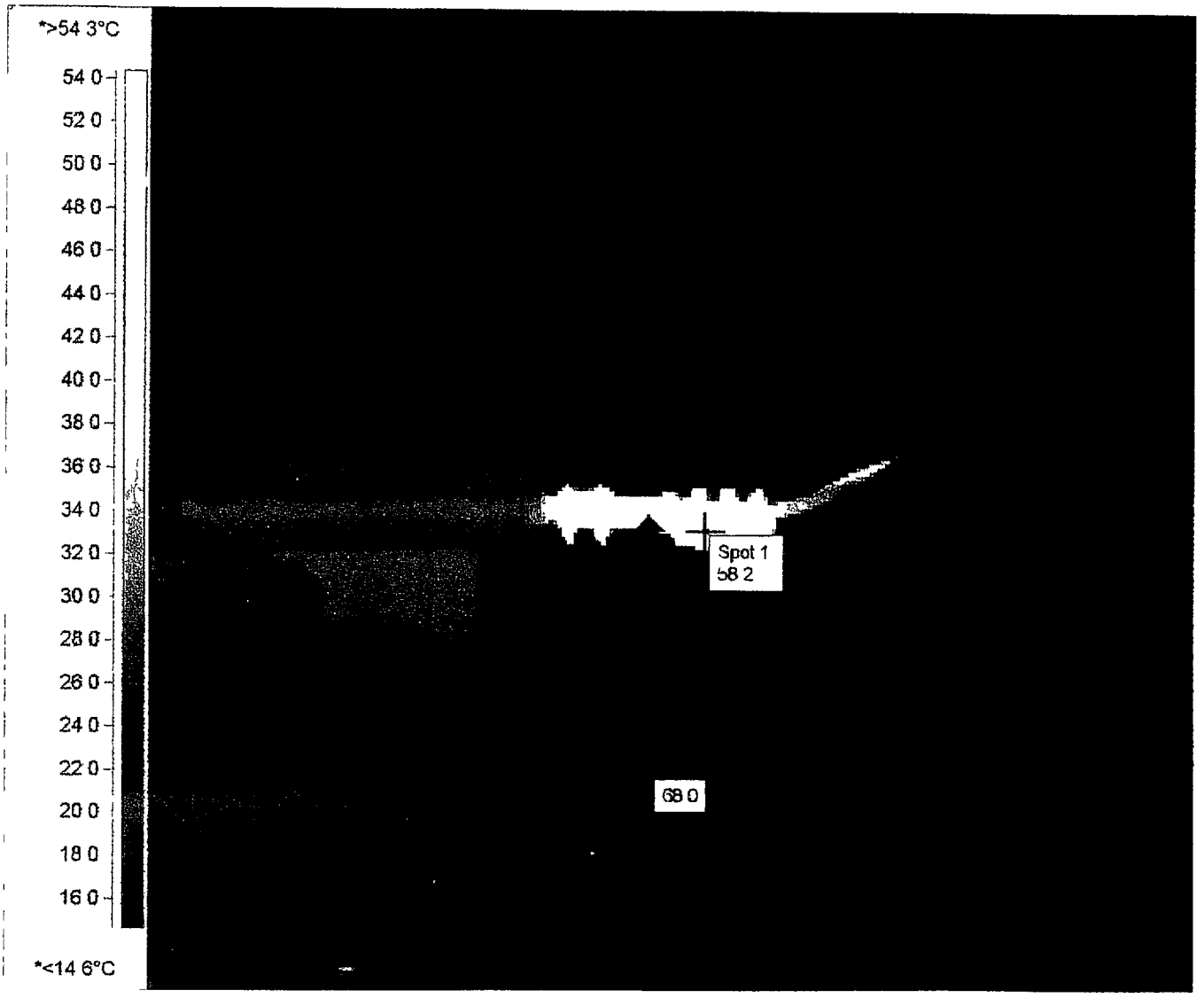
Semaphores not working properly

Lamp on alarm panel not working

Transformer T1 132/11 kV – Breaker is out of service – jumpered out Does the relaying accommodate this?

132KV S/STN,MADHUBAN-PG Clamp,Red Phase

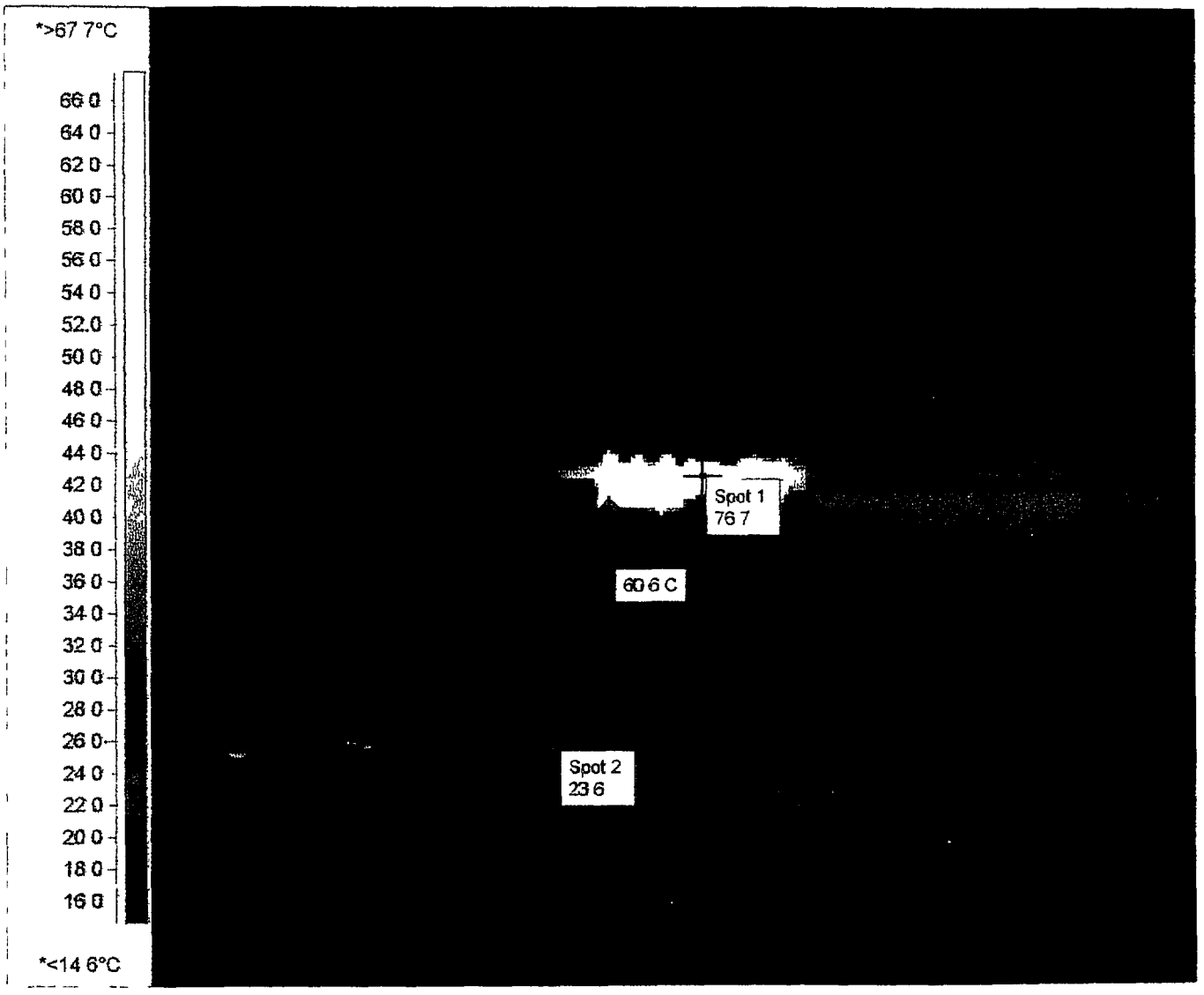
G15 TIF



inframetrics TherMonitor 95 11/27/98 4 09 34 PM

132KV S/STN,MADHUBAN-CT Connector Blue Phase

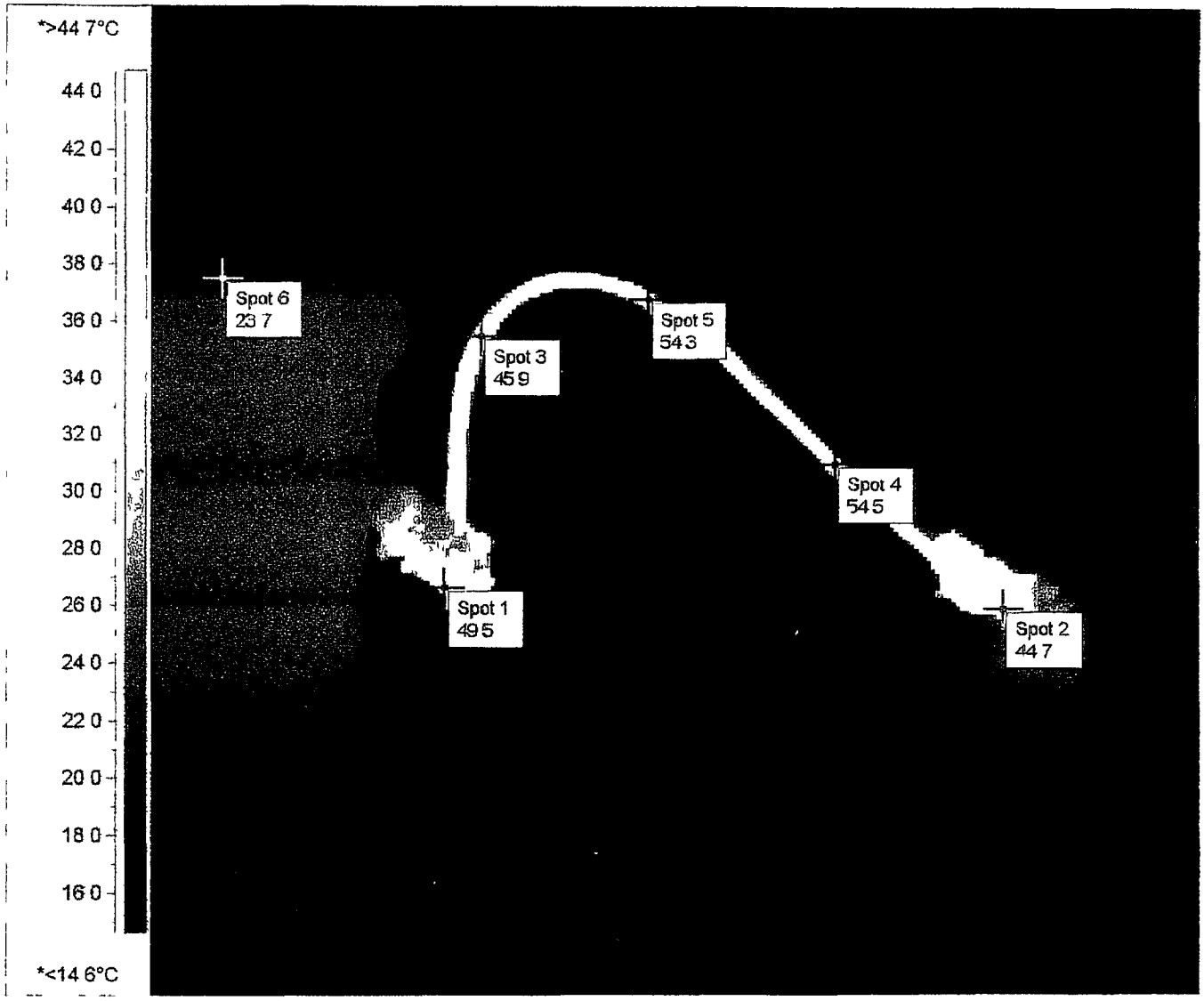
G14 TIF



inframetrics TherMonitor 95 11/27/98 4 00 27 PM

132KV S/STN,MADHUBAN-33KV Jumper,yellow Phase

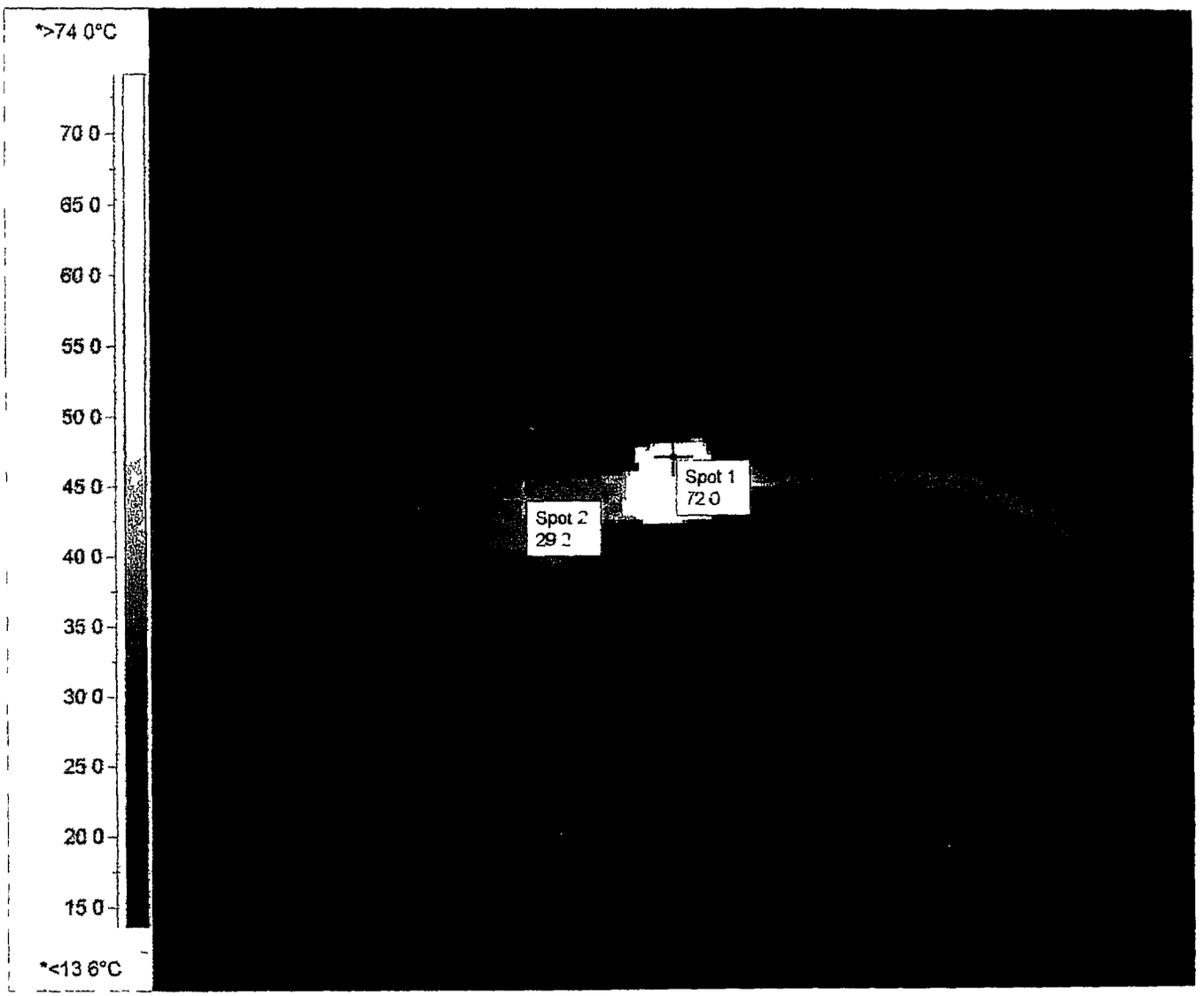
G13 TIF



inframetrics TherMonitor 95 11/27/98 3 52 06 PM

132KV S/STN,MADHUBAN-33KV Isolator,Red Phase

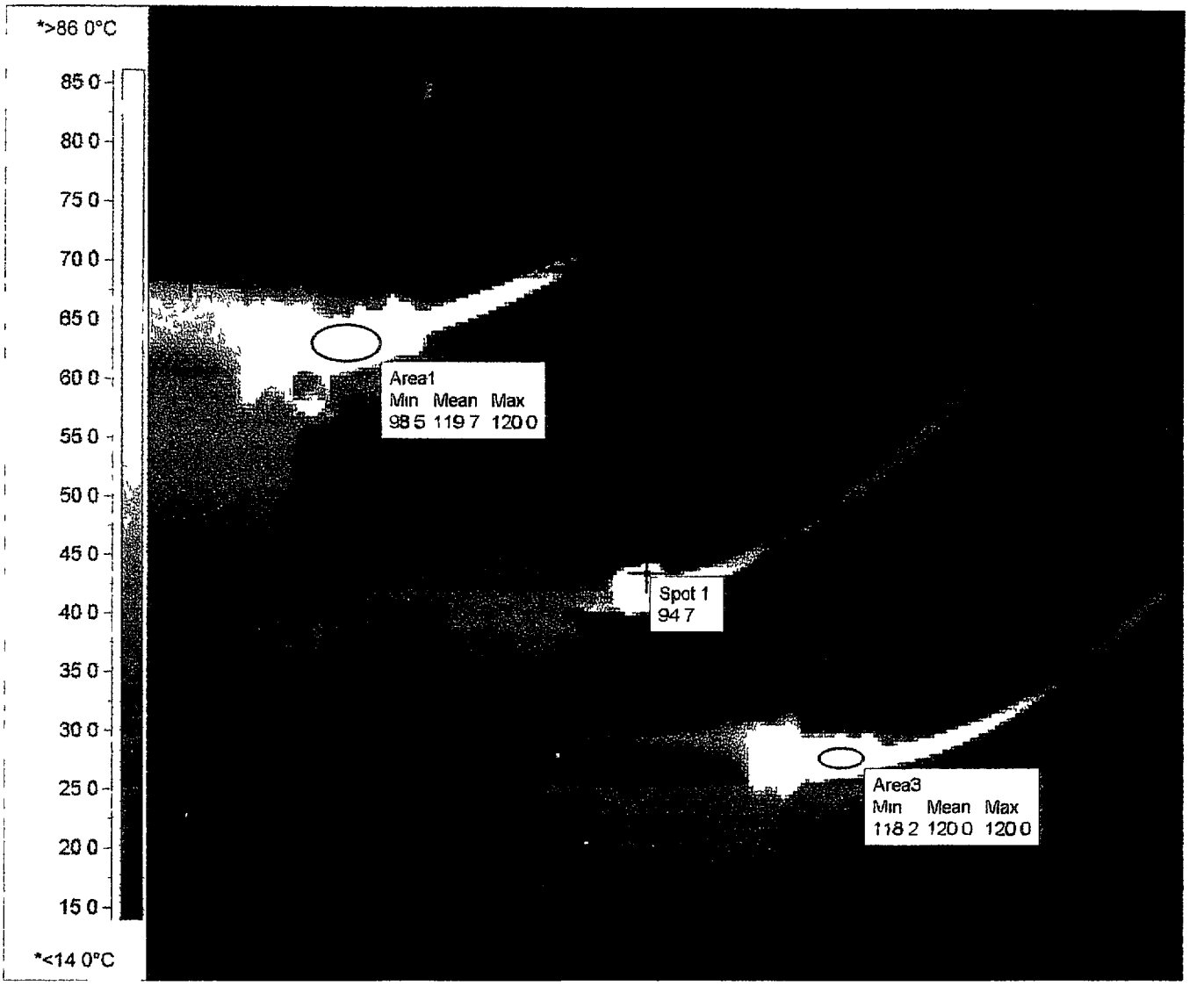
G12 TIF



inframetrics TherMonitor 95 11/27/98 3 43 20 PM

132 KV S/STN MABHUBAN-33KV Line CT

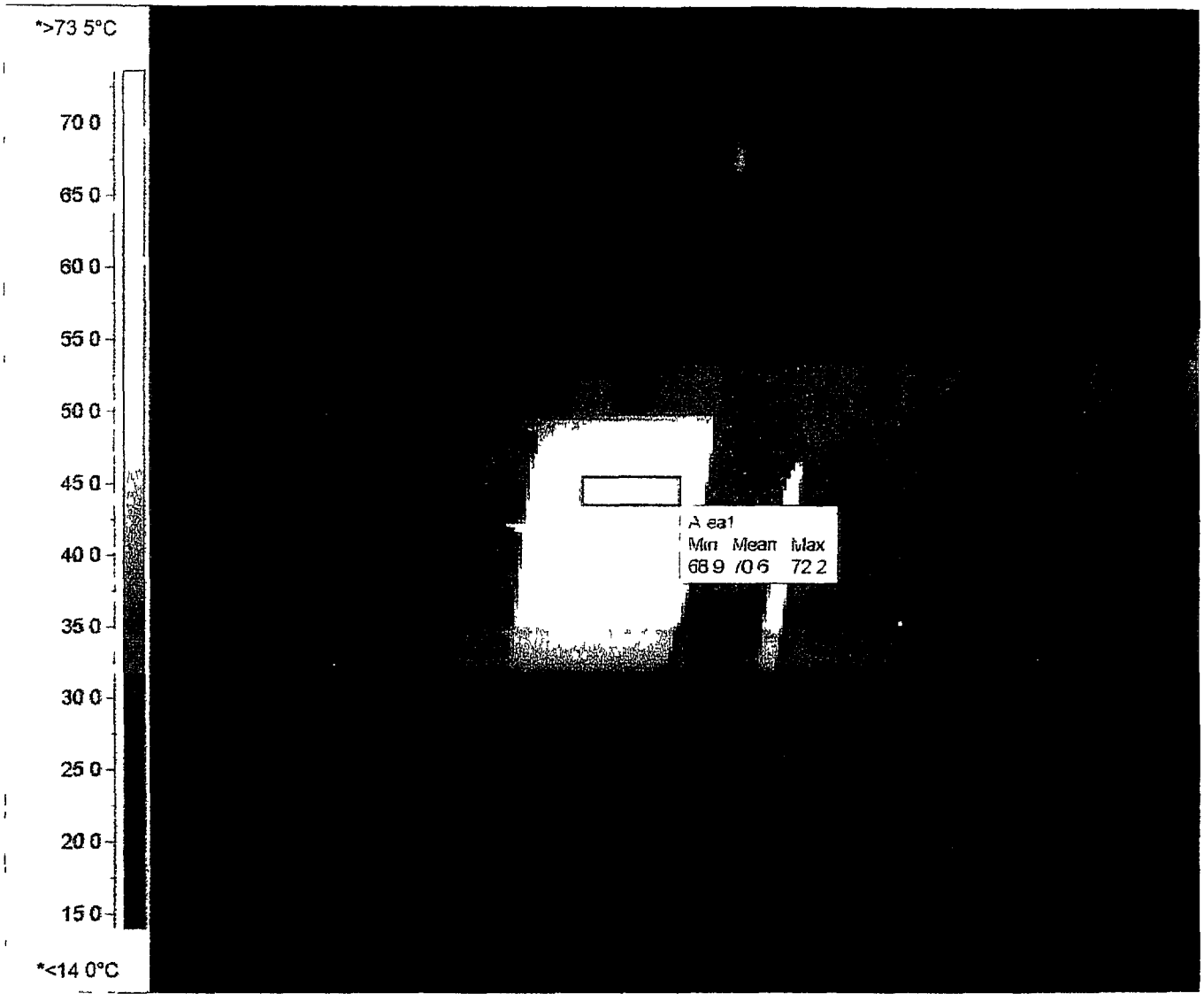
G11 TIF



inframetrics TherMonitor 95 11/27/98 3 33 39 PM

200KVA DISTRIBUTION T/FRin MIG Colony HAP Complex

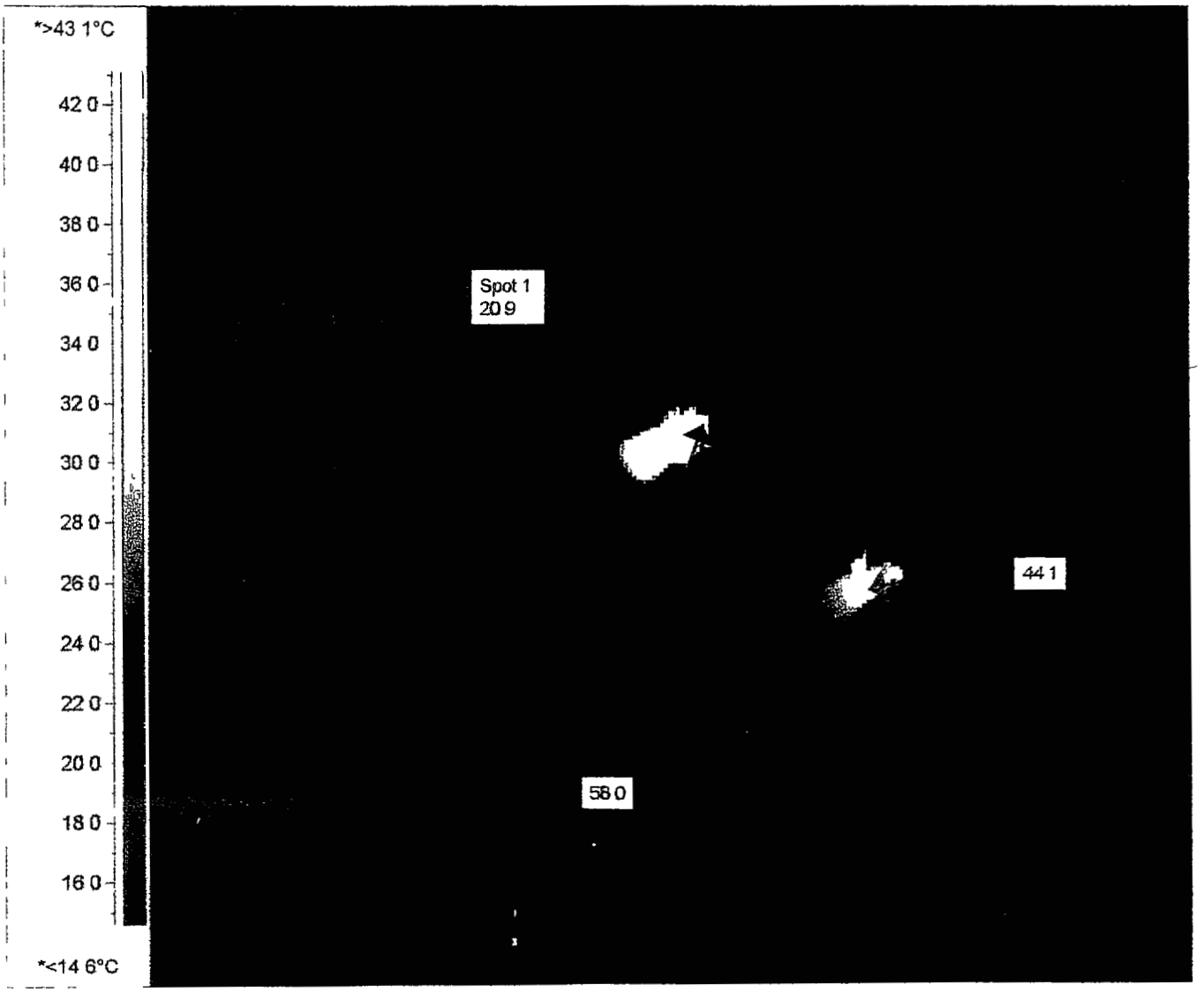
H08 TIF



inframetrics TherMonitor 95 11/27/98 6 45 32 PM

100KVA T/FR Yellow Phase from Overhead Line-11KV GO Switch

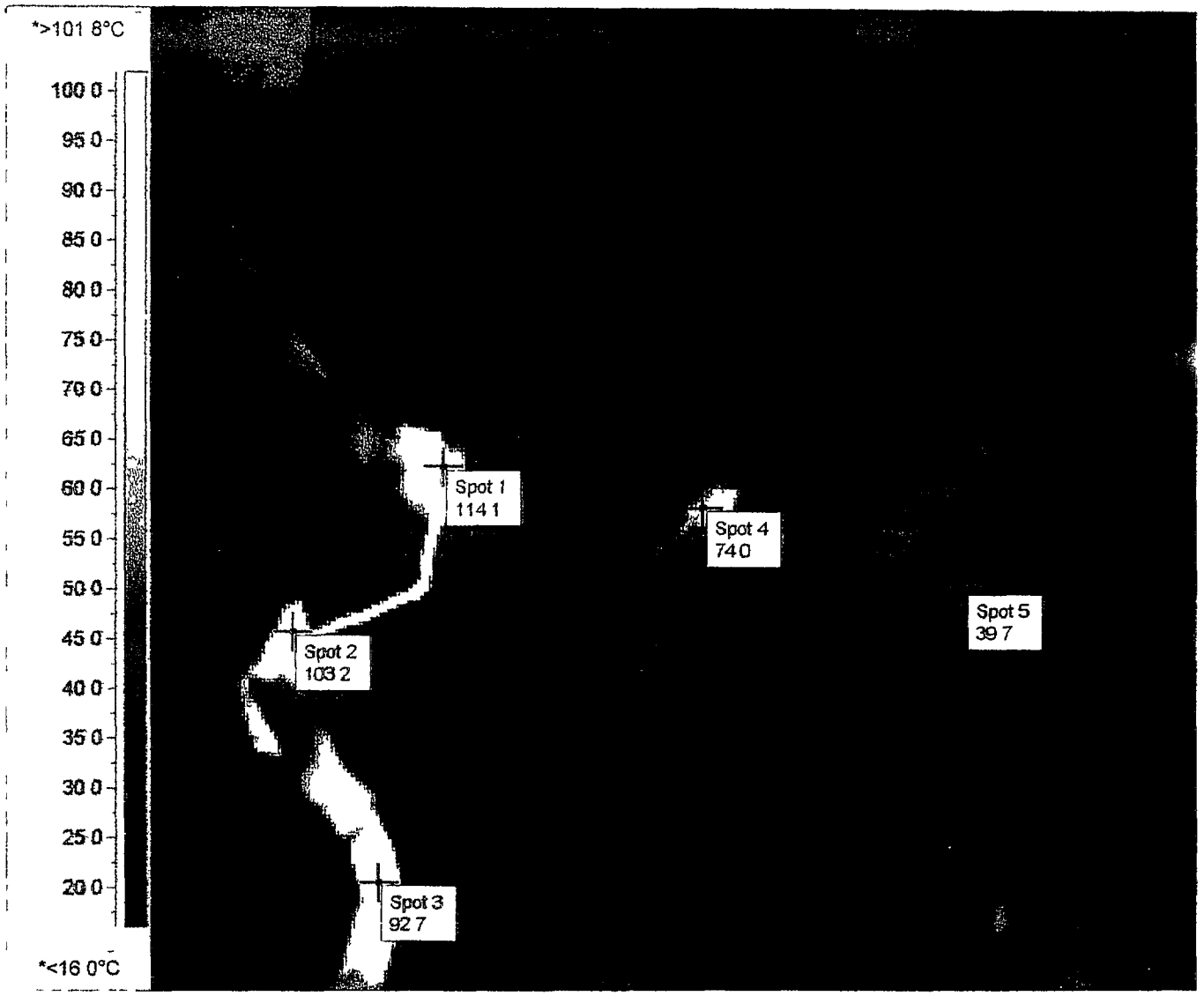
H07 TIF



inframetrics TherMonitor 95 11/27/98 6 37 06 PM

100KVA T/FR MIG GATE NO 5 FUSE UNIT

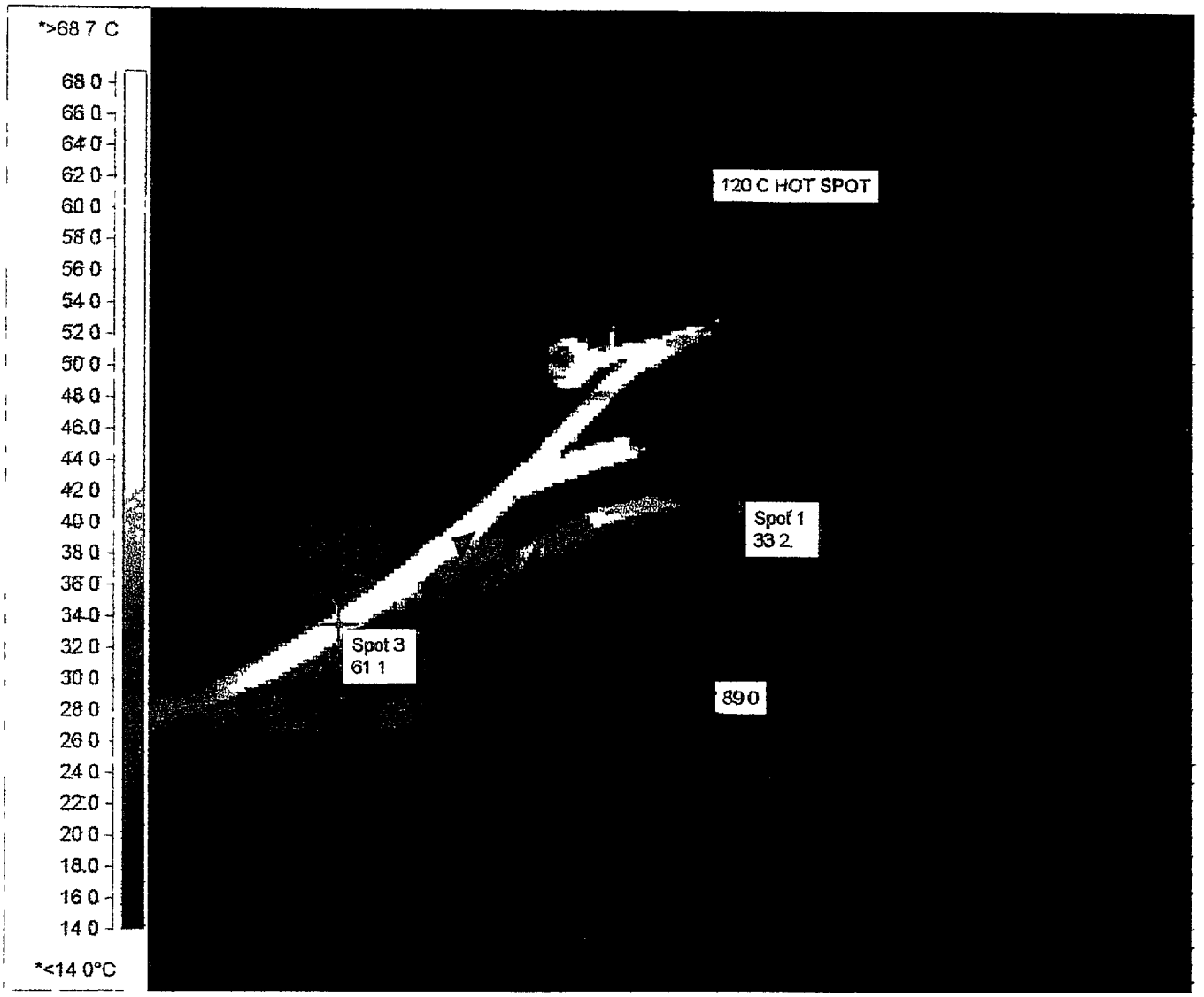
H06 TIF



inframetrics TherMonitor 95 11/27/98 6 24 58 PM

COMMON POLE OF 100KVA T/FR MIG GATE NO 5

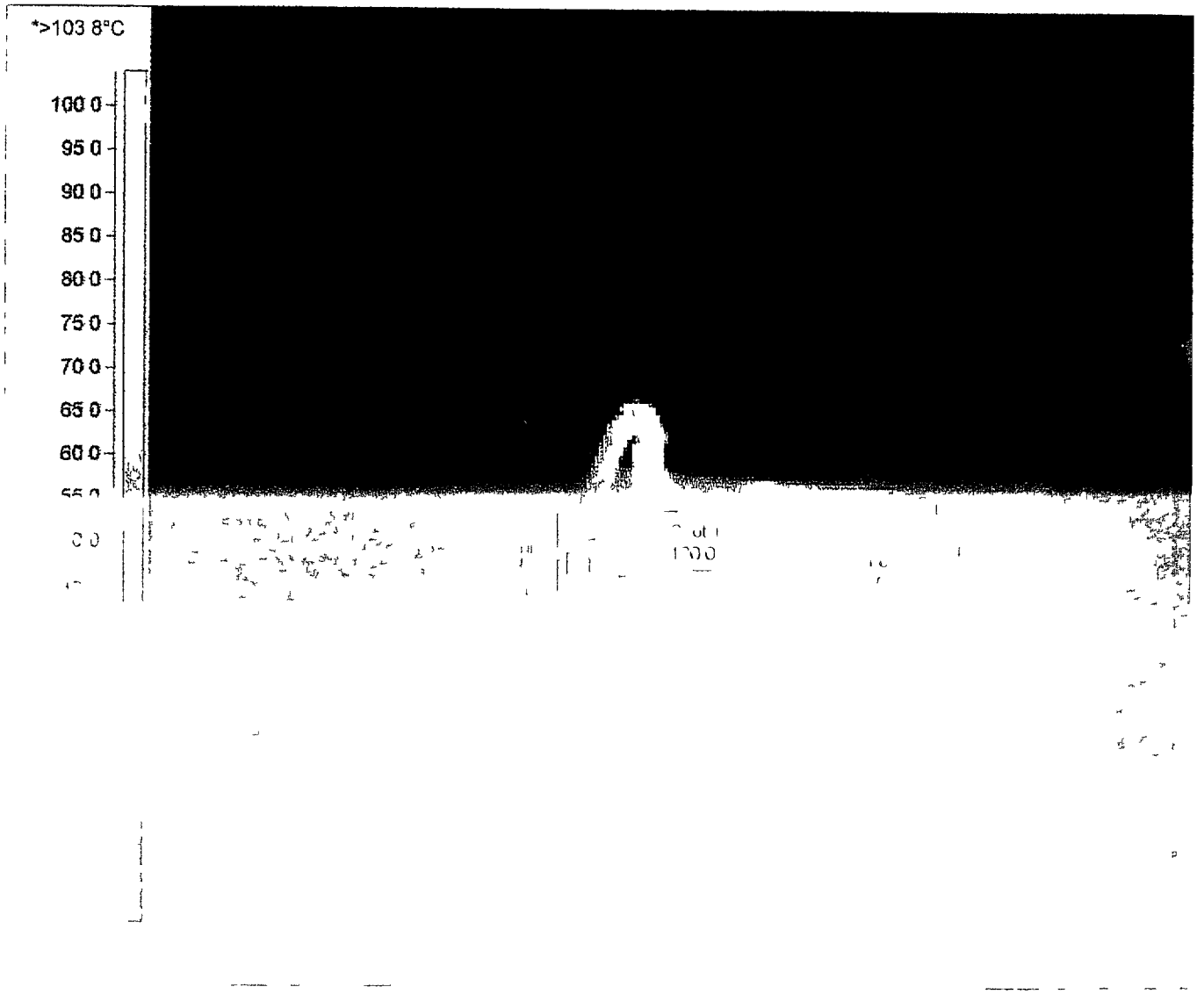
H05 TIF



inframetrics TherMonitor 95 11/27/98 6 15 38 PM

100 KVA T/FR ON HAP NEAR MIG GATE NO 5

H04 TIF

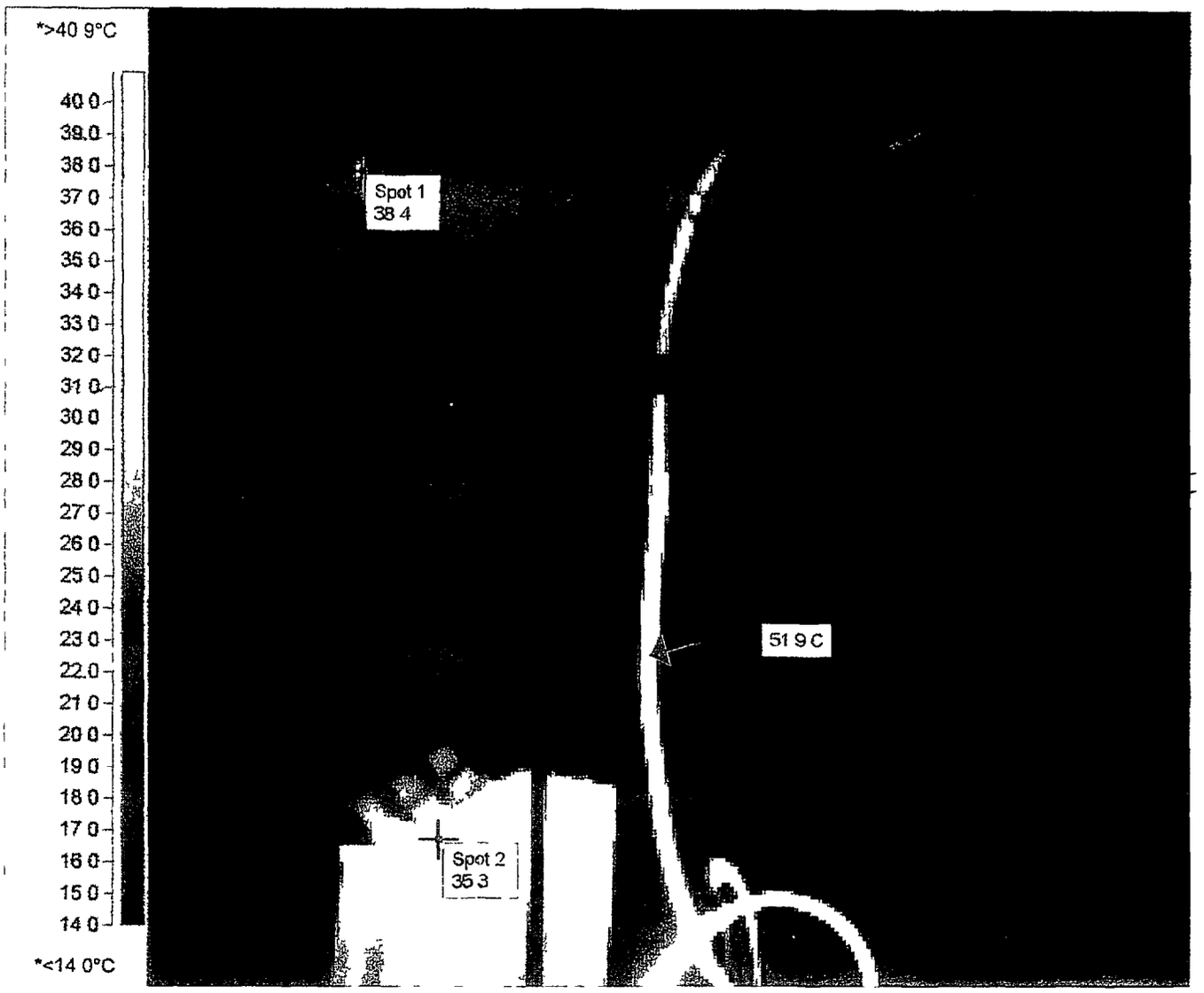


inframetrics TherMonitor 95 11/27/98 5 58 44 PM

198

11KV Bajidauri Feeder T/fr 63KVA

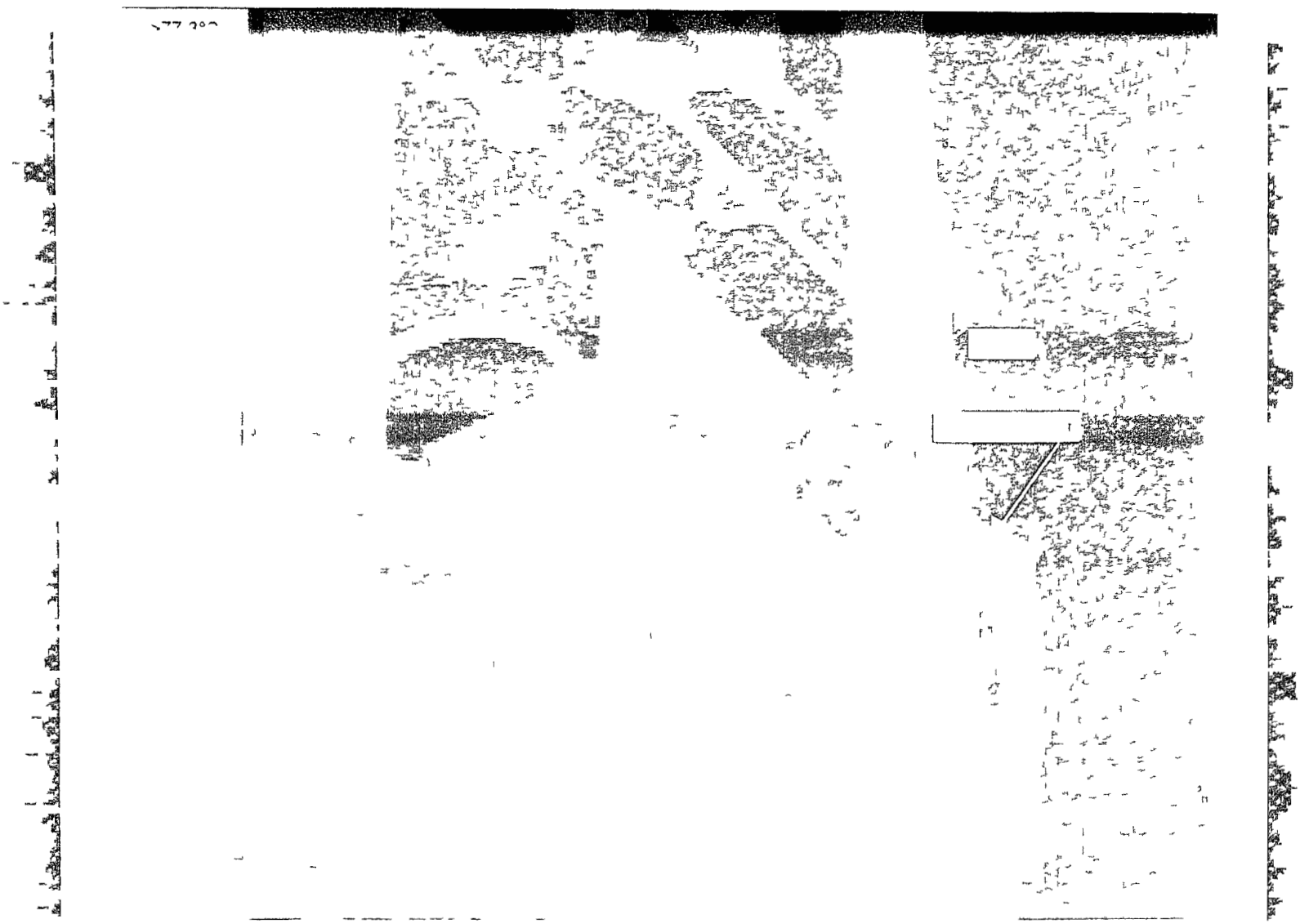
H03 TIF



inframetrics TherMonitor 95 11/27/98 6 05 53 PM

11KV Bajidauri Feeder Tfr, 63KVA

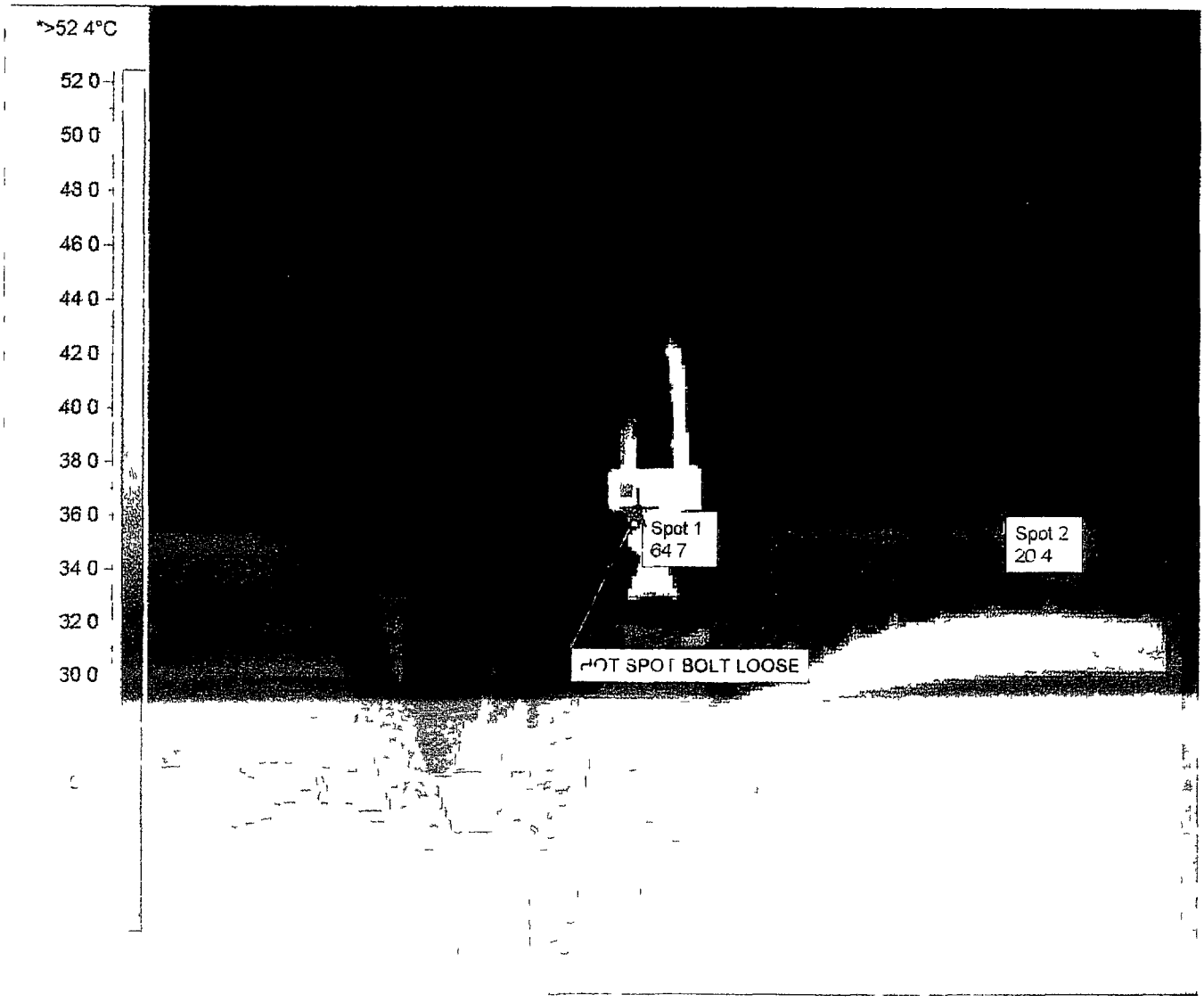
H02 TIF



inframetrics TherMonitor 95 11/27/98 5 04 57 PM

132KV S/STN,MADHUBAN-Blue Phase of 132/11 Kv Tfr

H01 TIF

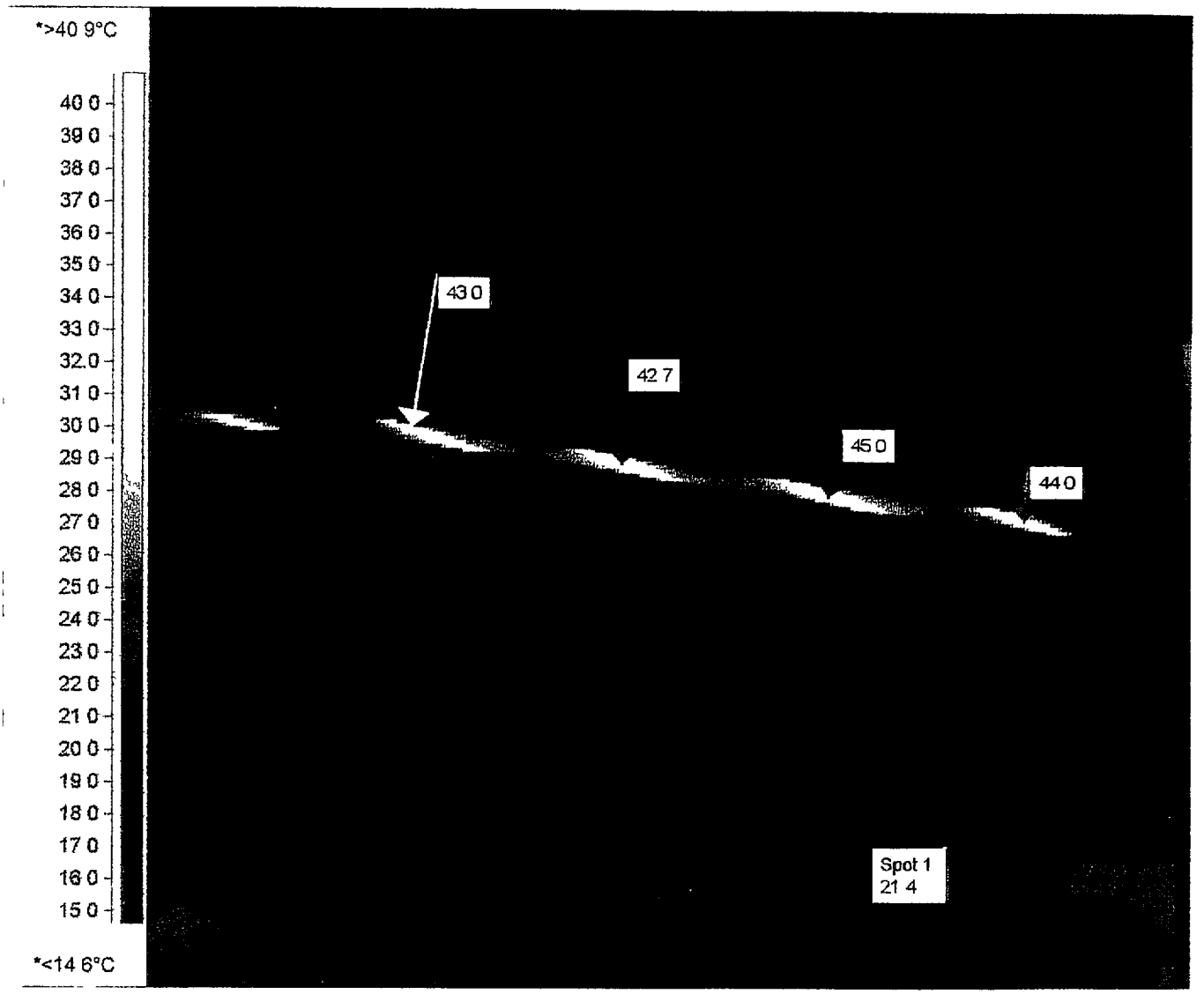


inframetrics TherMonitor 95 11/27/98 4 52 08 PM

201

132KV S/STN,MADHUBAN-33KV Jumper Yellow Phase,HSIDC

G16 TIF



inframetrics TherMonitor 95 11/27/98 4 19 46 PM

202

HISAR 220 kV SWITCHYARD

Hisar 220 kV Substation Deficiencies

Inadequate ground on breaker

Trench covers missing

Static wires not providing adequate protection

Birds nests have been built inside disconnect switch corona rings

PVC cables exposed to sunlight

Tight bending radius in jumper conductors

Rod gaps not properly aligned

Surge counters not mounted at proper height They are too high cannot be read

Surge counter not working (counter remains at 0)

11 kV metal-clad breaker status not known Bulb out, ammeter reads zero, inside flag has no indicator

Wrong bolts on connector on 220 kV disconnect switch - has caused corrosion

Inadequate transformer containment area on 11 kV transformer

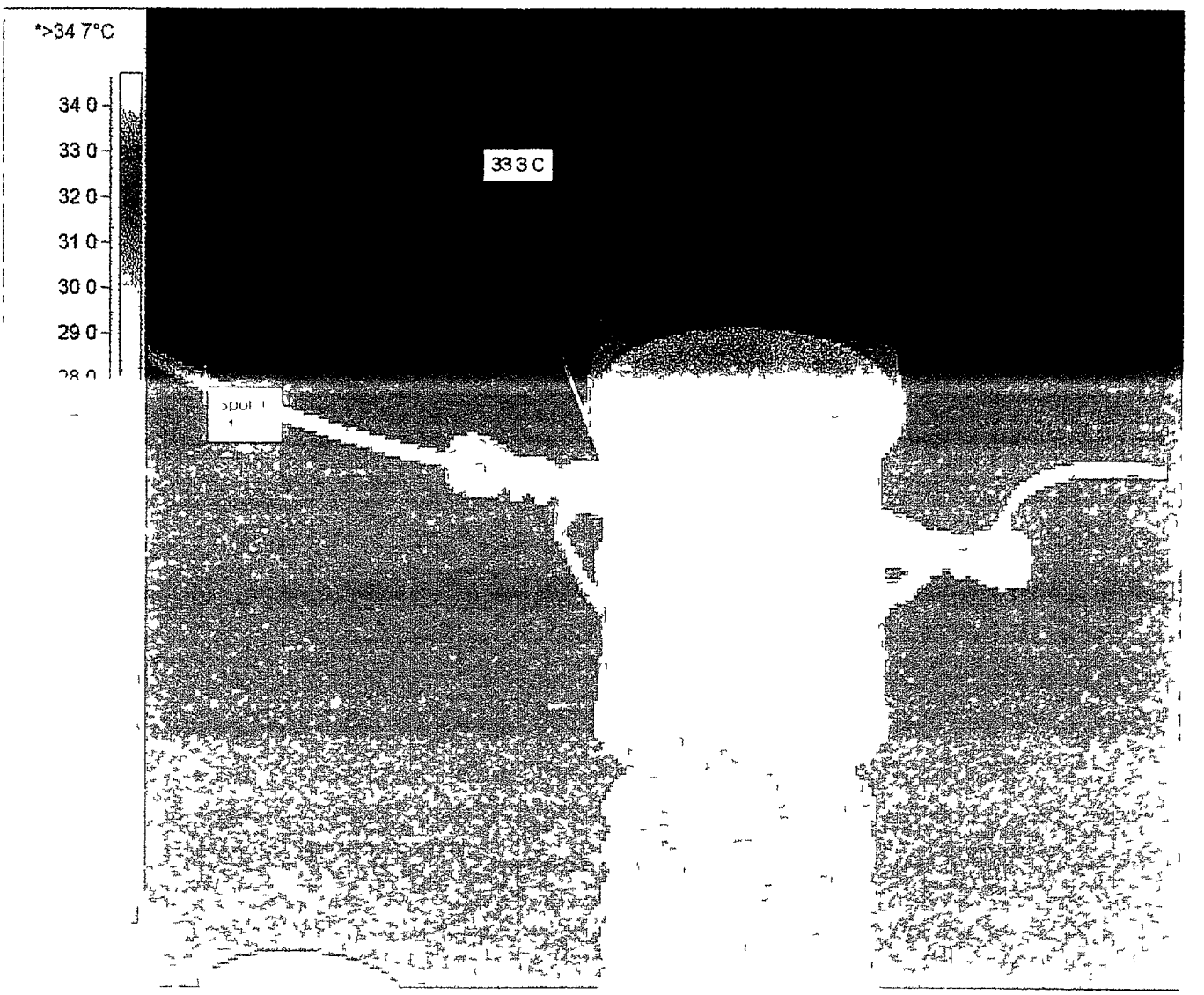
Indadequate crushed rock protection

Control House

CT ratio on 220 kV panel not marked

220 Kv Substation,Hisar-Y Phase CT incoming conn of 132 KV T/fr side

F16 TMW

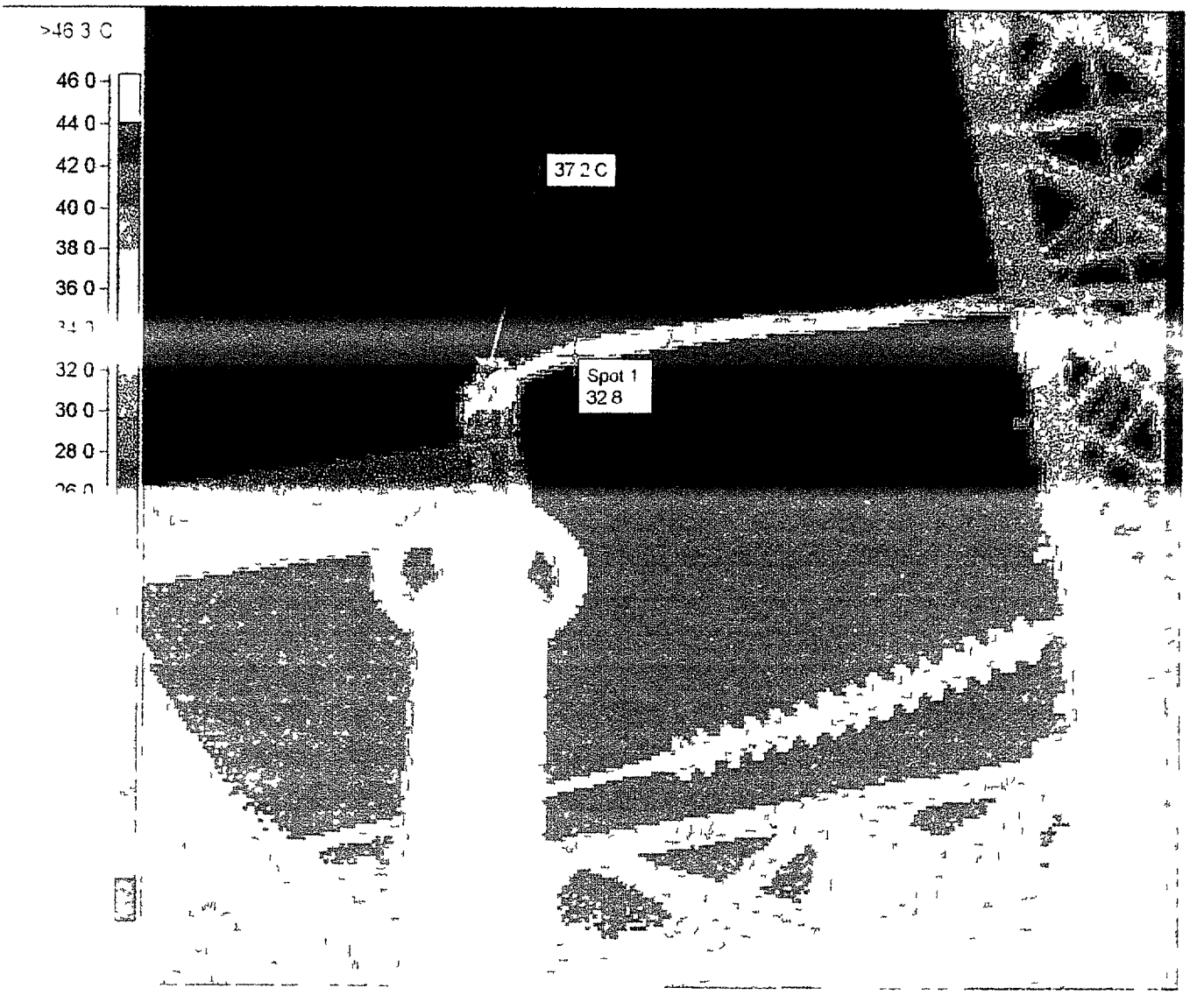


inframetrics TherMonitor 95 12/8/98 3 43 04 PM

205

220 Kv Substation, Hisar-Y Phase Jumper of 100 MVA T/fr

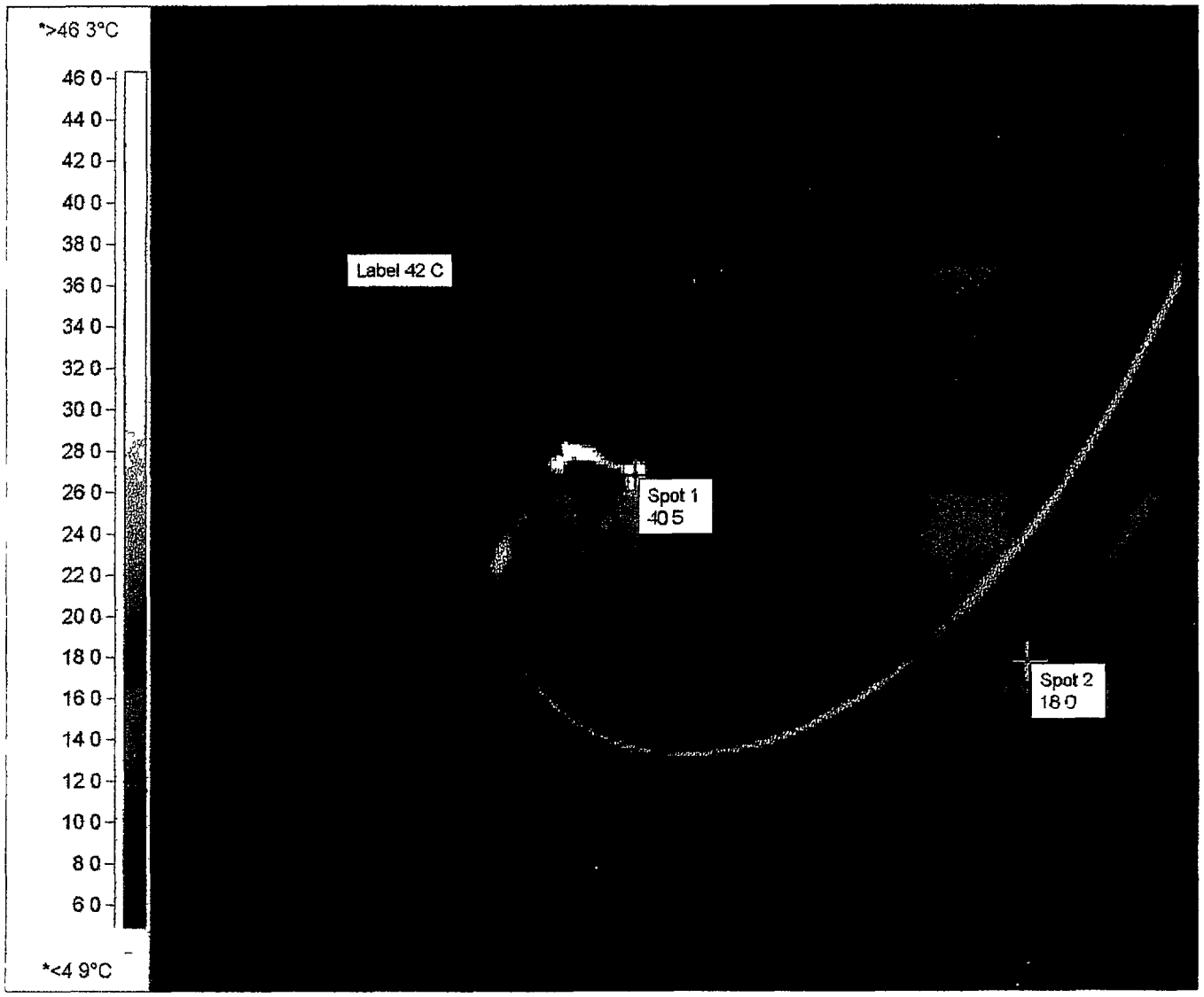
F15 TMW



inframetrics TherMonitor 95 12/8/98 3 41 04 PM

220 Kv Substation,Hisar-Y Phase Bus no 2 above CT

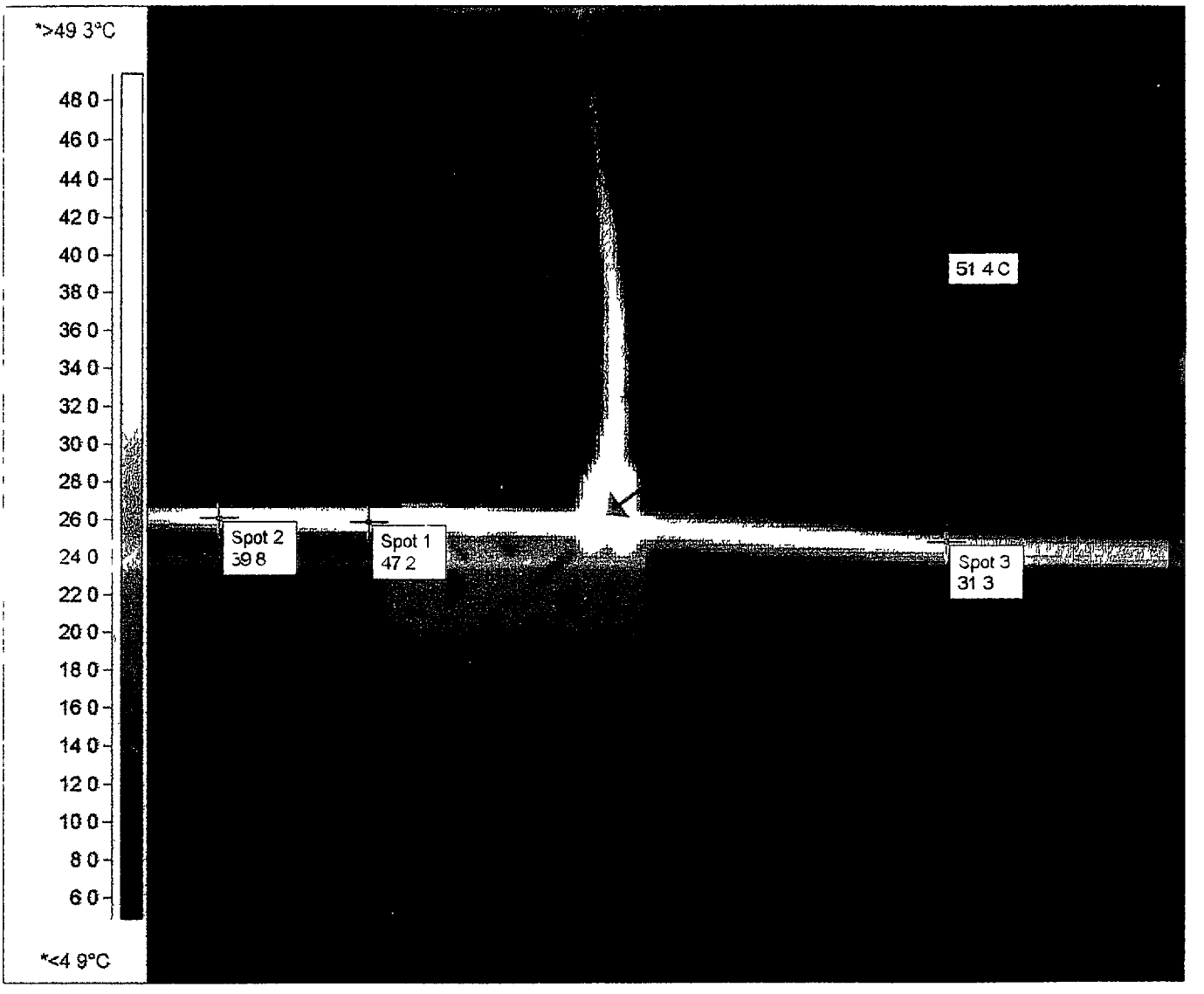
F14 TMW



inframetrics TherMonitor 95 12/8/98 3 39 14 PM

220 Kv Substation,Hisar-Ckt no 3 Y Phase connecting bus

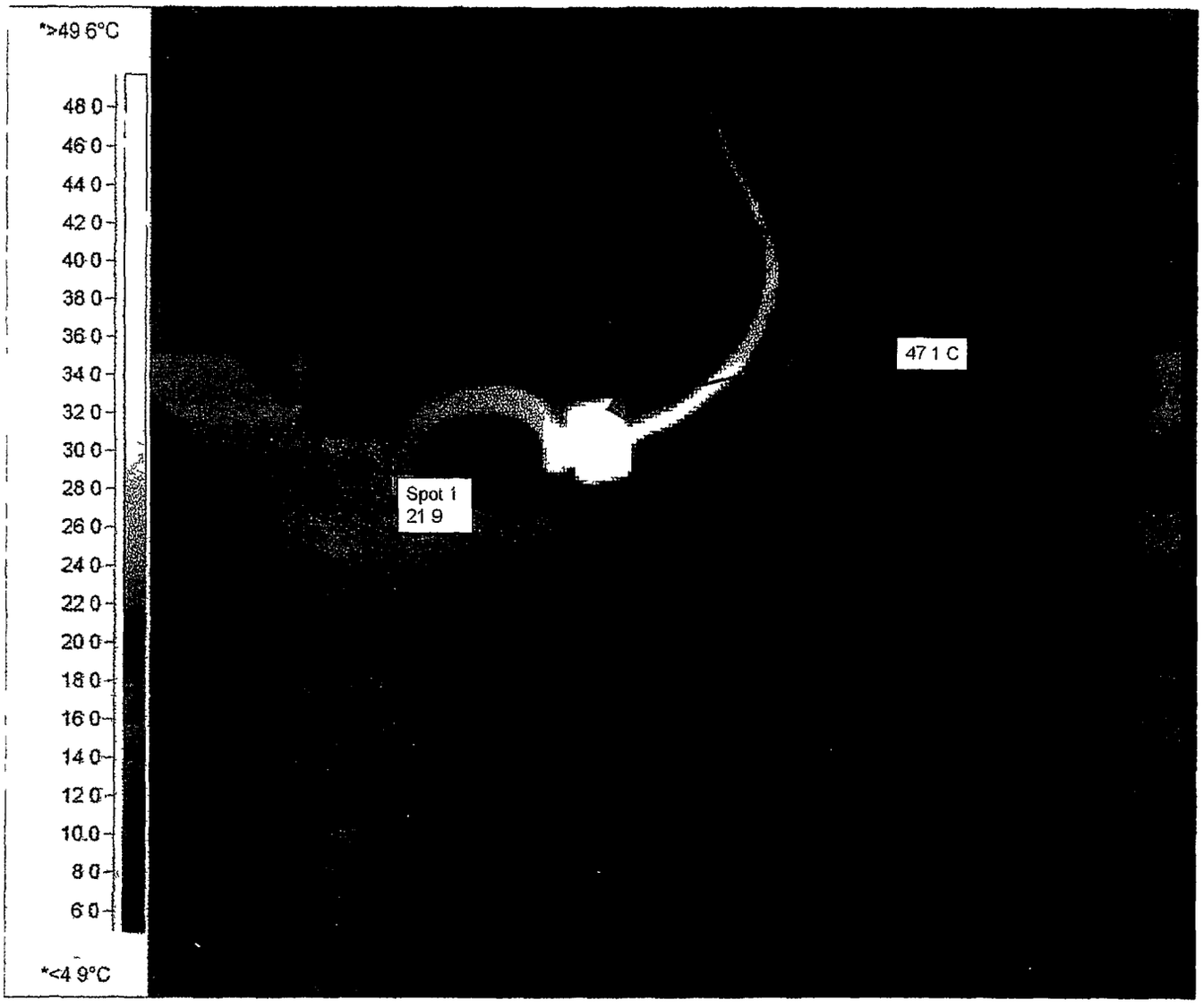
F13 TMW



inframetrics TherMonitor 95 12/8/98 3 35 32 PM

220 Kv Substation,Hisar-Ckt no 4 Yellow phase incoming

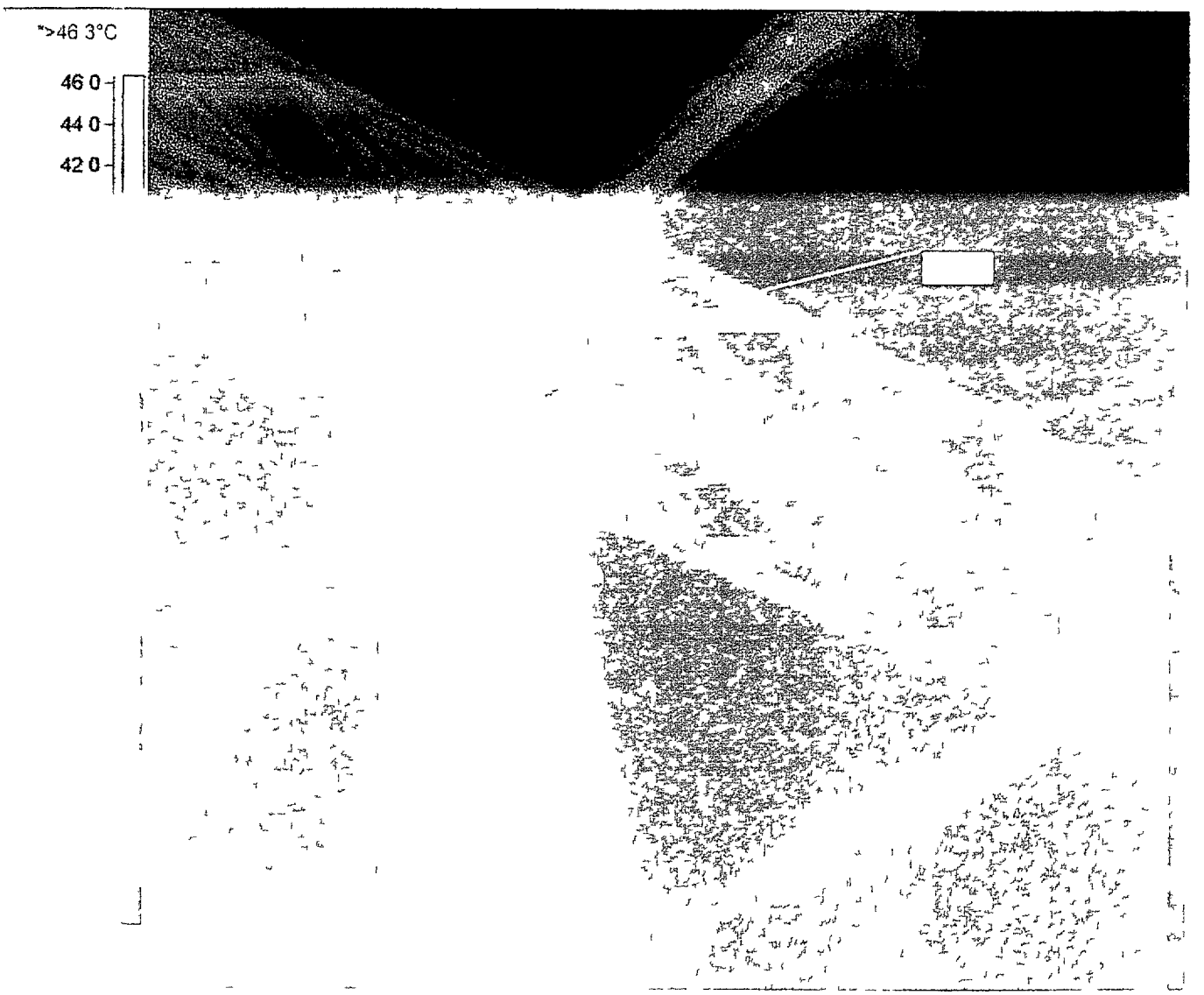
F12 TMW



inframetrics TherMonitor 95 12/8/98 3 30 44 PM

220 Kv Substation,Hisar-Ckt n0 4 Blue CT Outgoing

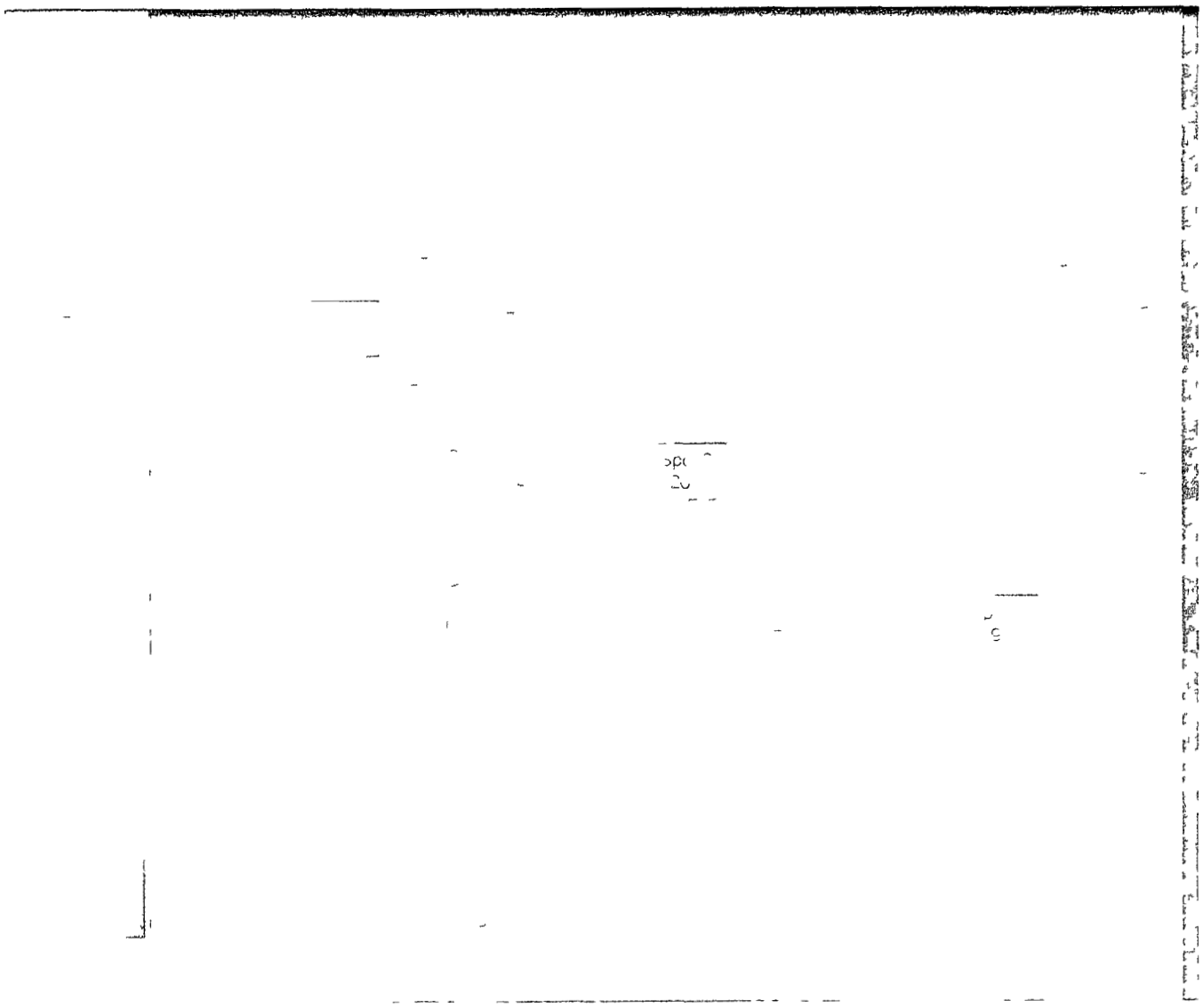
F11 TMW



inframetrics TherMonitor 95 12/8/98 3 07 16 PM

GO Switch of 200 KVA T/fr opp T B Hospital

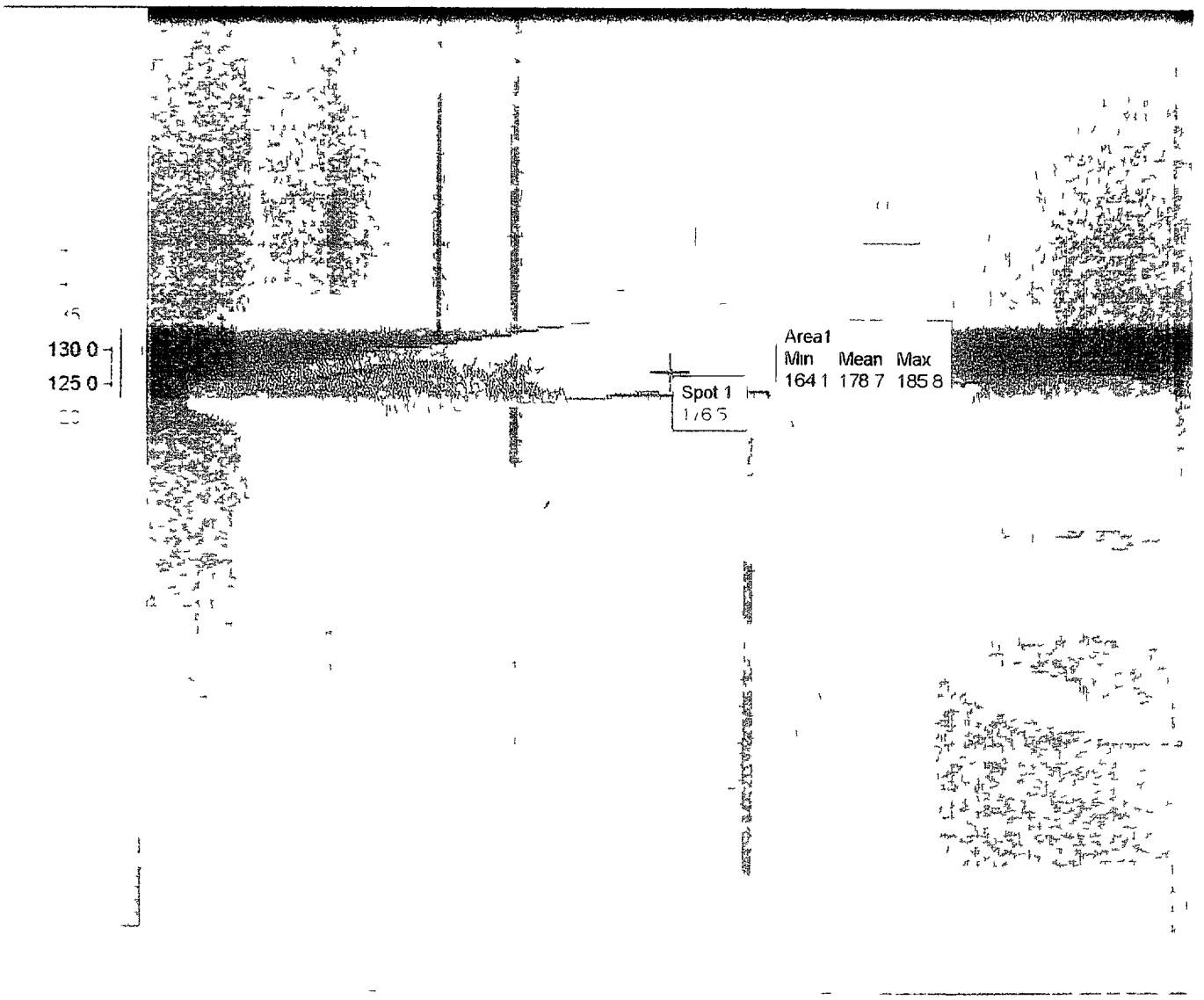
G06 TMW



inframetrics TherMonitor 95 12/8/98 1 34 56 PM

Nagori Gate T/fr 1000 KVA

G08 TMW

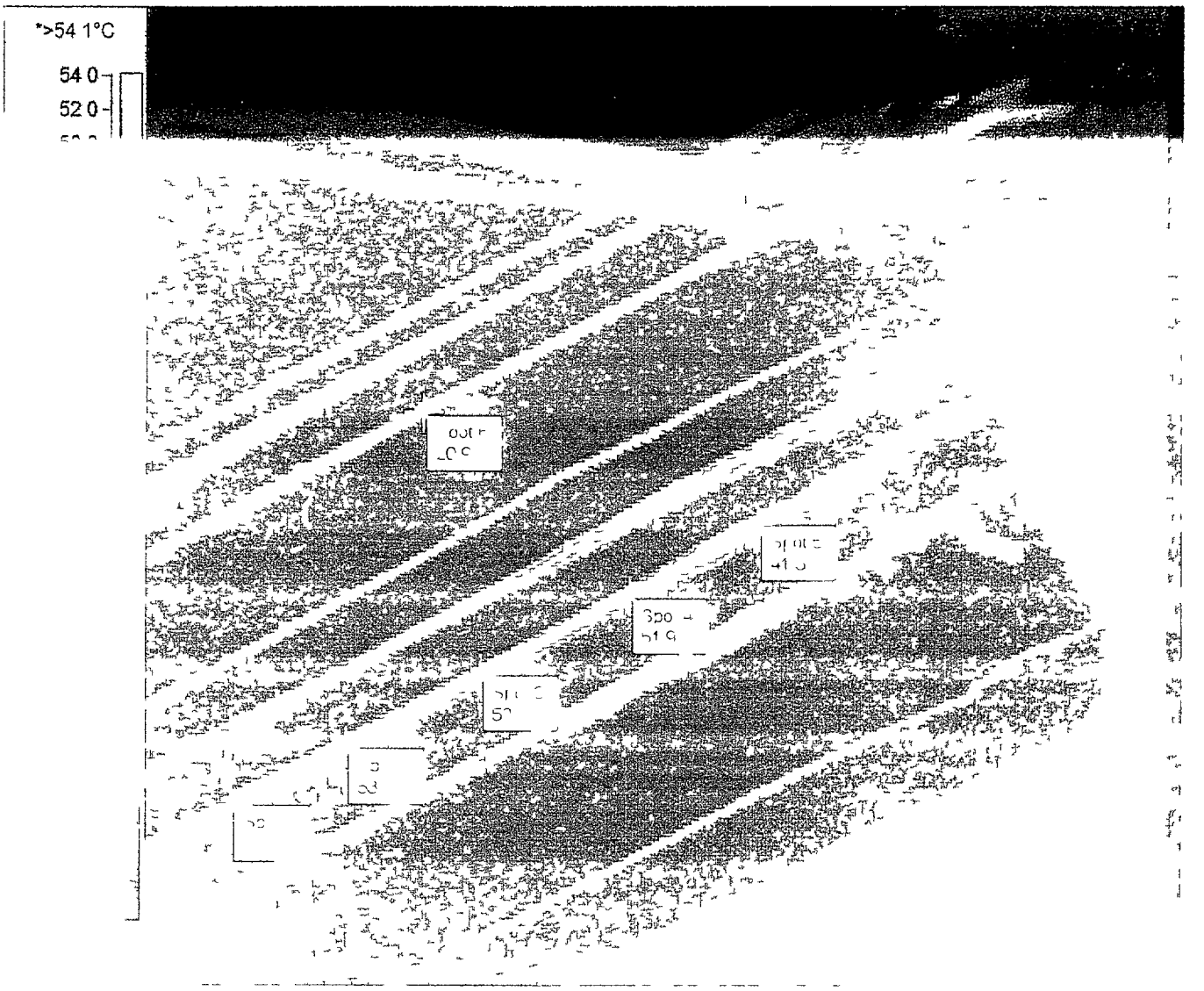


inframetrics TherMonitor 95 12/8/98 1 52 42 PM

212

POLE POINT OPP MANDIR

G09 TMW

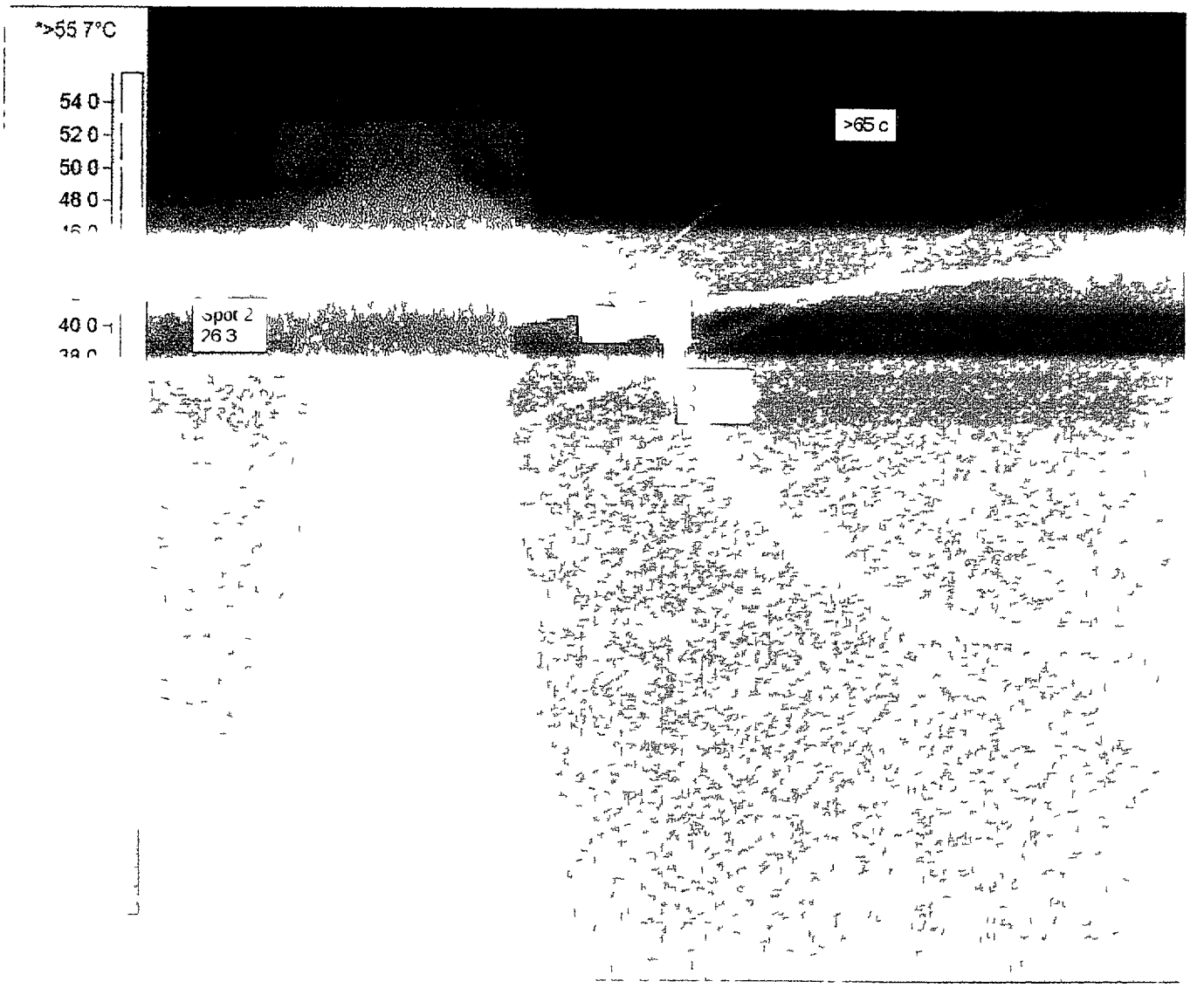


inframetrics TherMonitor 95 12/8/98 2 18 59 PM

213

220 KV SubStation,Hisar-Red Phase Line 3 CT Jumper

F10 TMW



inframetrics TherMonitor 95 12/8/98 3 02 01 PM

214

220 Kv Substation,Hisar-B Phase iso incoming conn of 132kv side

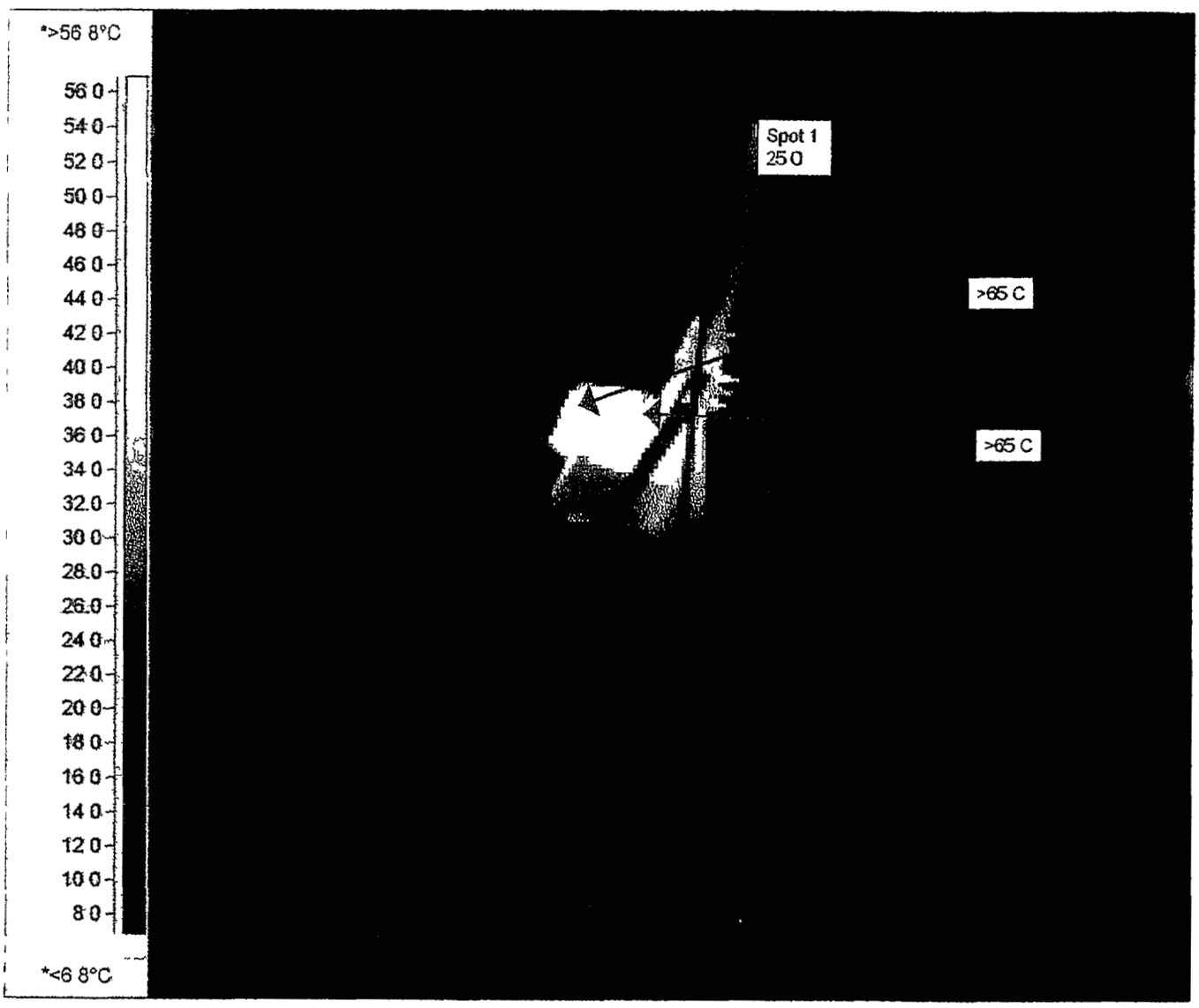
G01 TMW

inframetrics TherMonitor 95 12/8/98 1 27 38 PM

215

220 Kv Substation,Hisar-Y Phase incoming conn of Bus Isolator

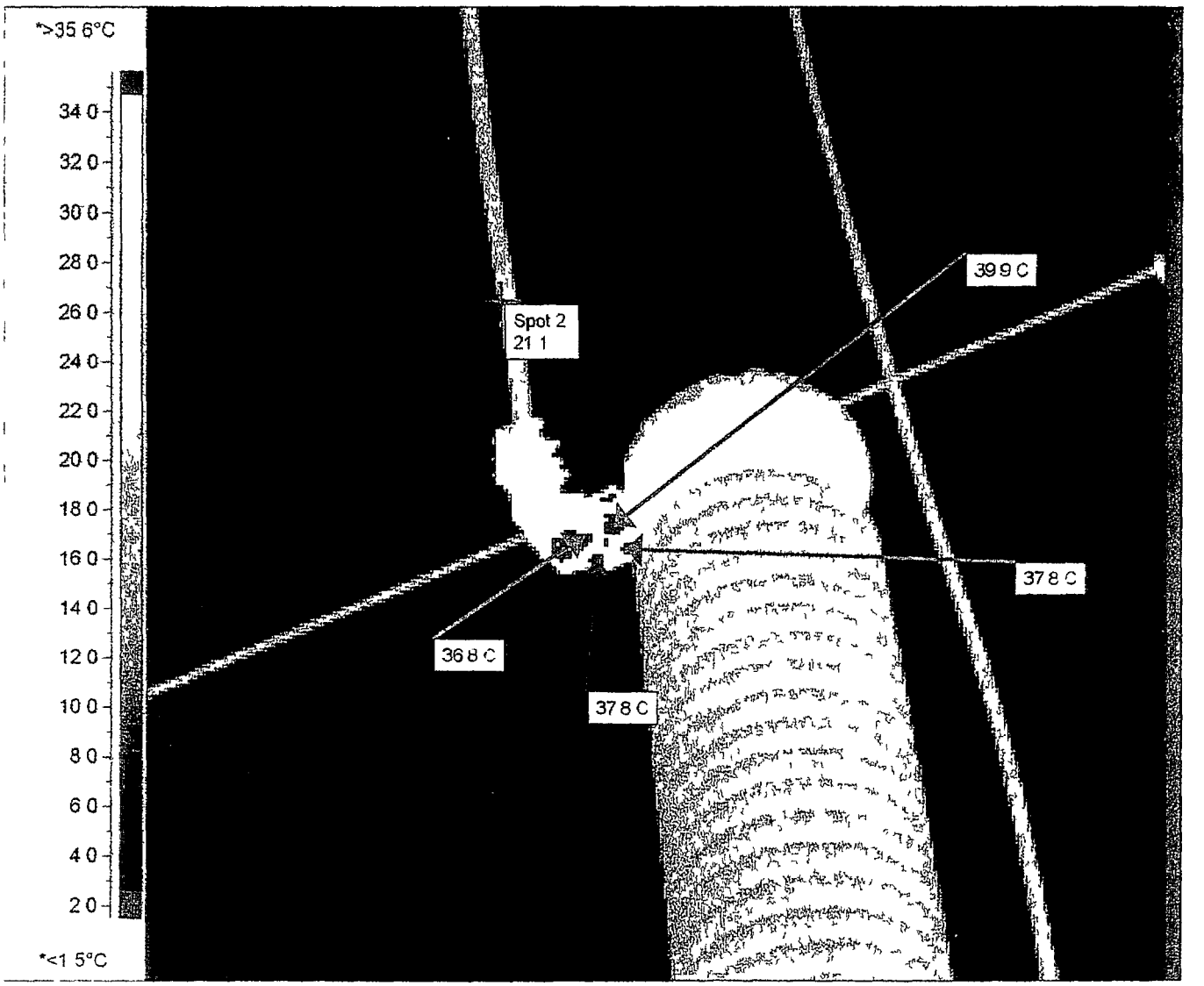
G02 TMW



inframetrics TherMonitor 95 12/8/98 1 29 53 PM

220 Kv Substation,Hisar-Incoming Jumper at 132 kv Breaker R Phase

G03 TMW

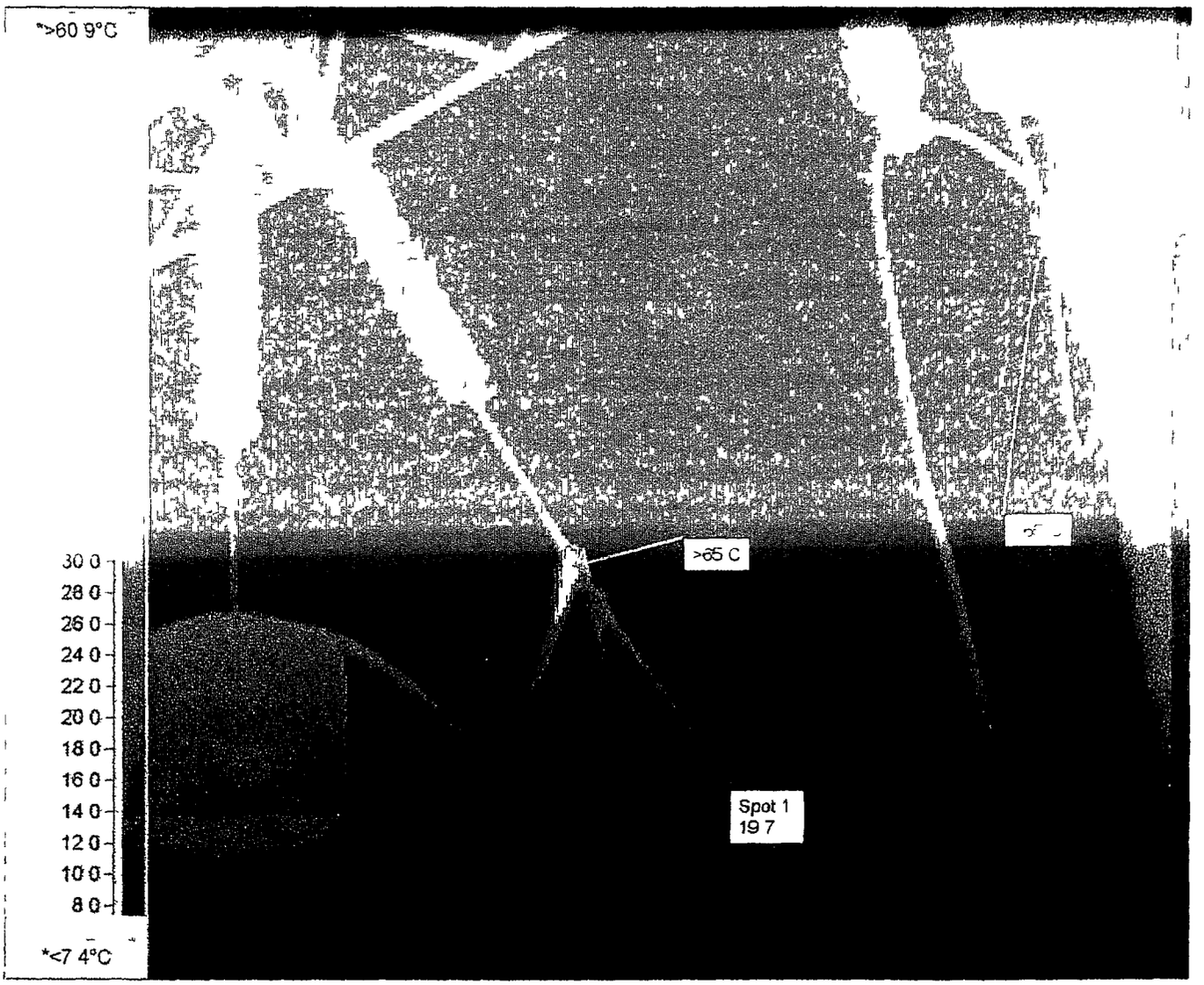


inframetrics TherMonitor 95 12/8/98 1 31 12 PM

217

220 Kv Substation,Hisar-B Phase jumper of 132 Kv line

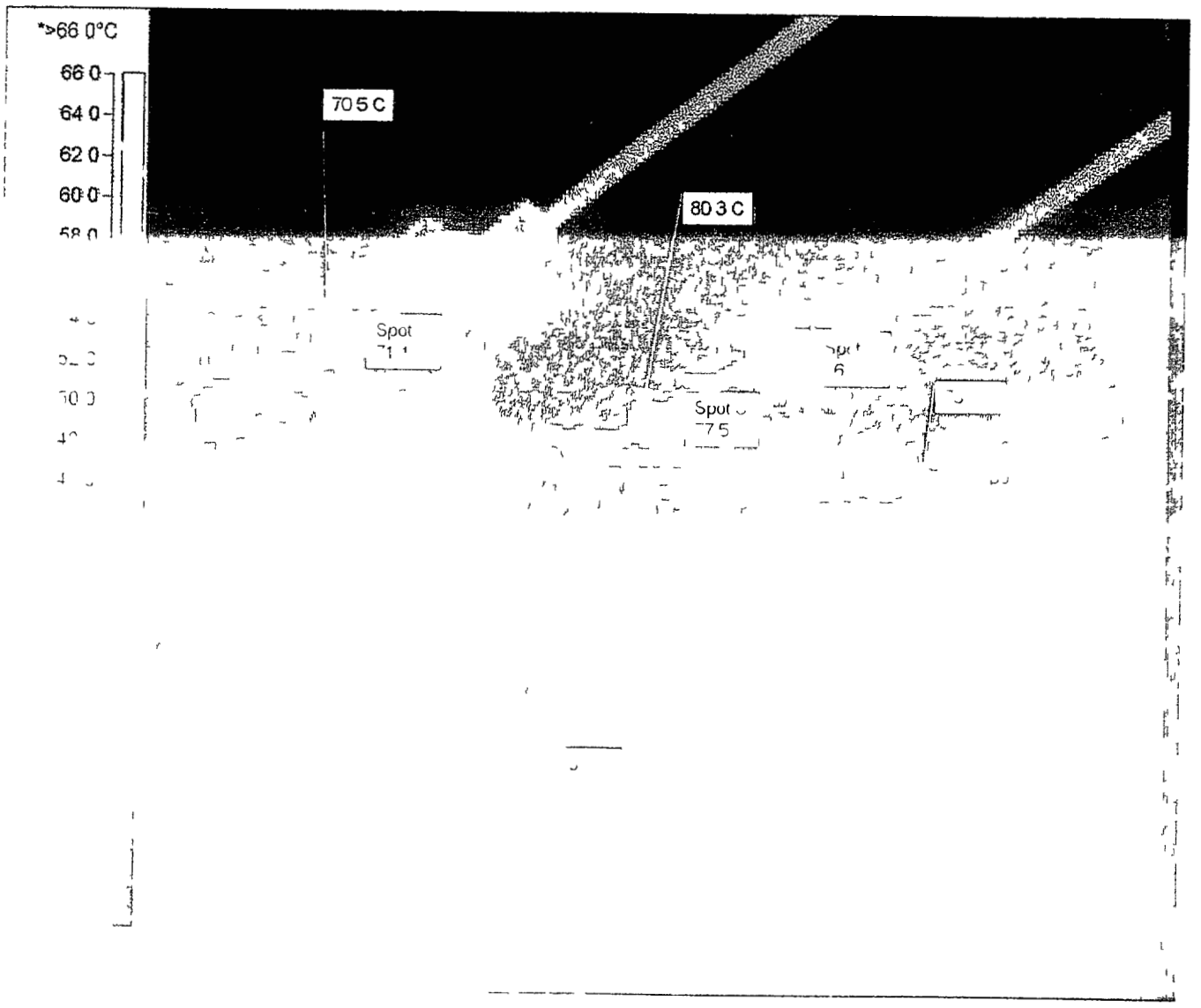
G04 TMW



inframetrics TherMonitor 95 12/8/98 1 32 08 PM

220 Kv Substation, Hisar-GO Switch of 11 Kv Tibba Line

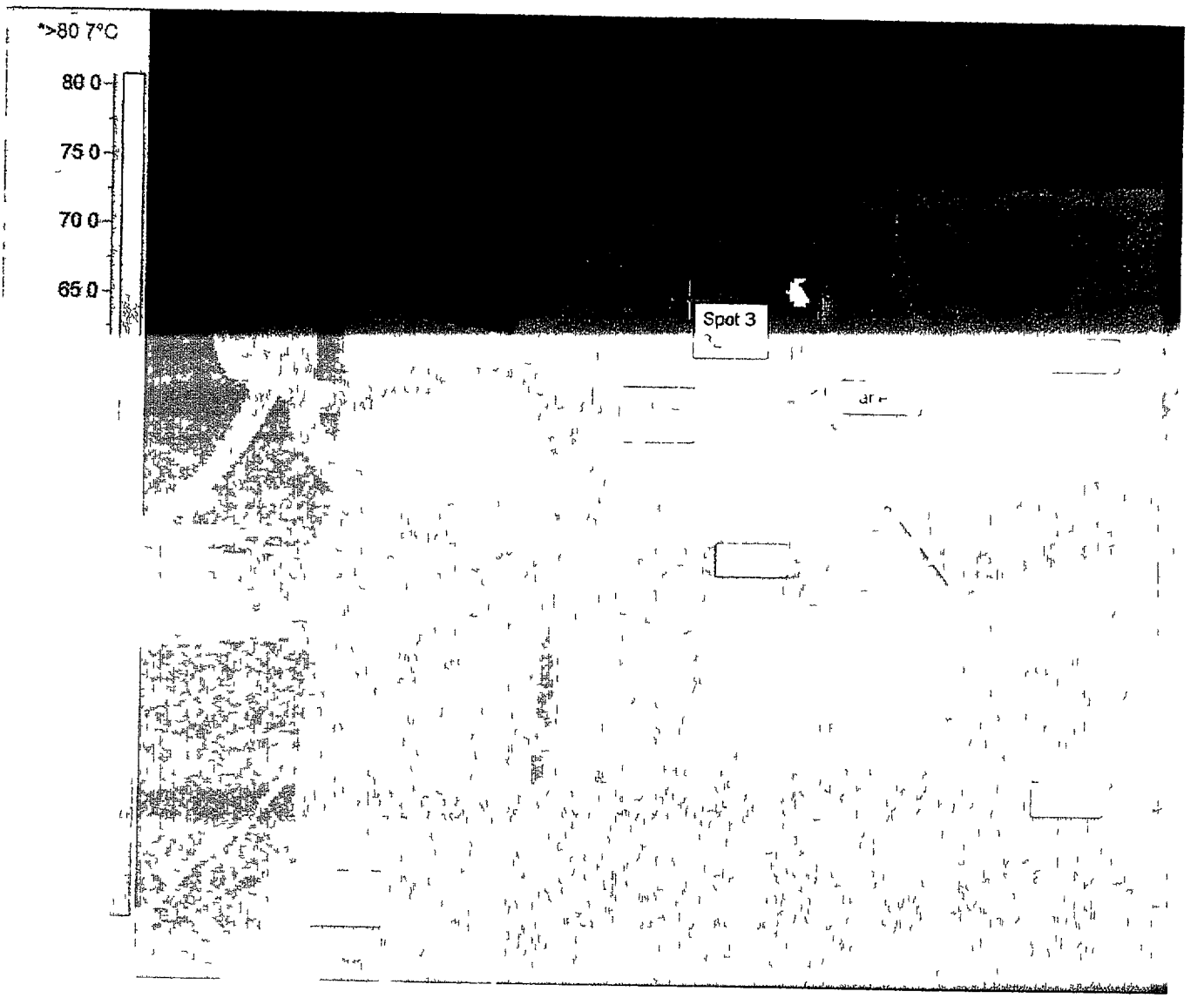
G05 TMW



inframetrics TherMonitor 95 12/8/98 1 33 41 PM

LT side of 200 KVA T/fr opp T B Hospital

G07 TMW

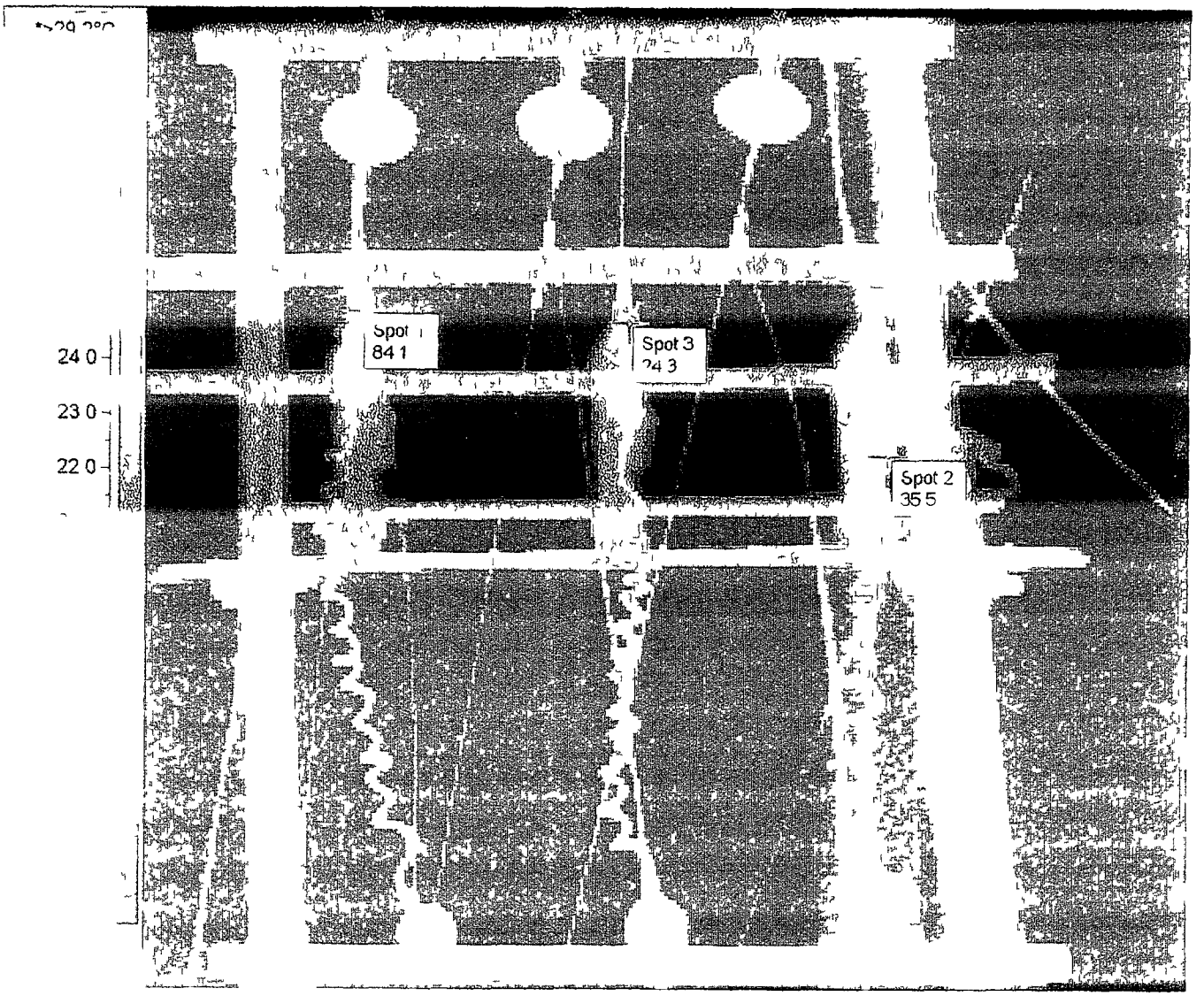


inframetrics TherMonitor 95 12/8/98 1 36 12 PM

220

DISTRIBUTION JUMPERS OPP T B HOSPITAL

C01 TMW



inframetrics TherMonitor 95 12/8/98 2 17 27 PM

BEER SWITCHYARD

Beer Substation Deficiencies

33 kV isolators - Bus connectors have tight bending radius Horizontal connectors were used instead of vertical connectors

Isolator does not have separate ground as is needed when the structure is bolted, rather than welded

Heater is switched off in outdoor breaker control panel

No manual control on SF6 132 kV breaker

Surger counter on L/A is incorrectly connected

Transformer oil containment area not adequate

Gasket is deteriorated on power transformer control panel

Poor seal on marshalling kiosk for CT - water has entered inside

Control cables laying on ground

33 kV jumpers have tight bending radius

No L/A on riser poles of 11 kV feeders

CT ratio not indicated on control panels of 132 kV/33 kV transformer

Spring charge indicator light not working

Indicating lights on metal clad switchgear panel for cap circuit breaker not working

Electrical spring charging not functional on 11 kV breakers Spring must be charged by hand

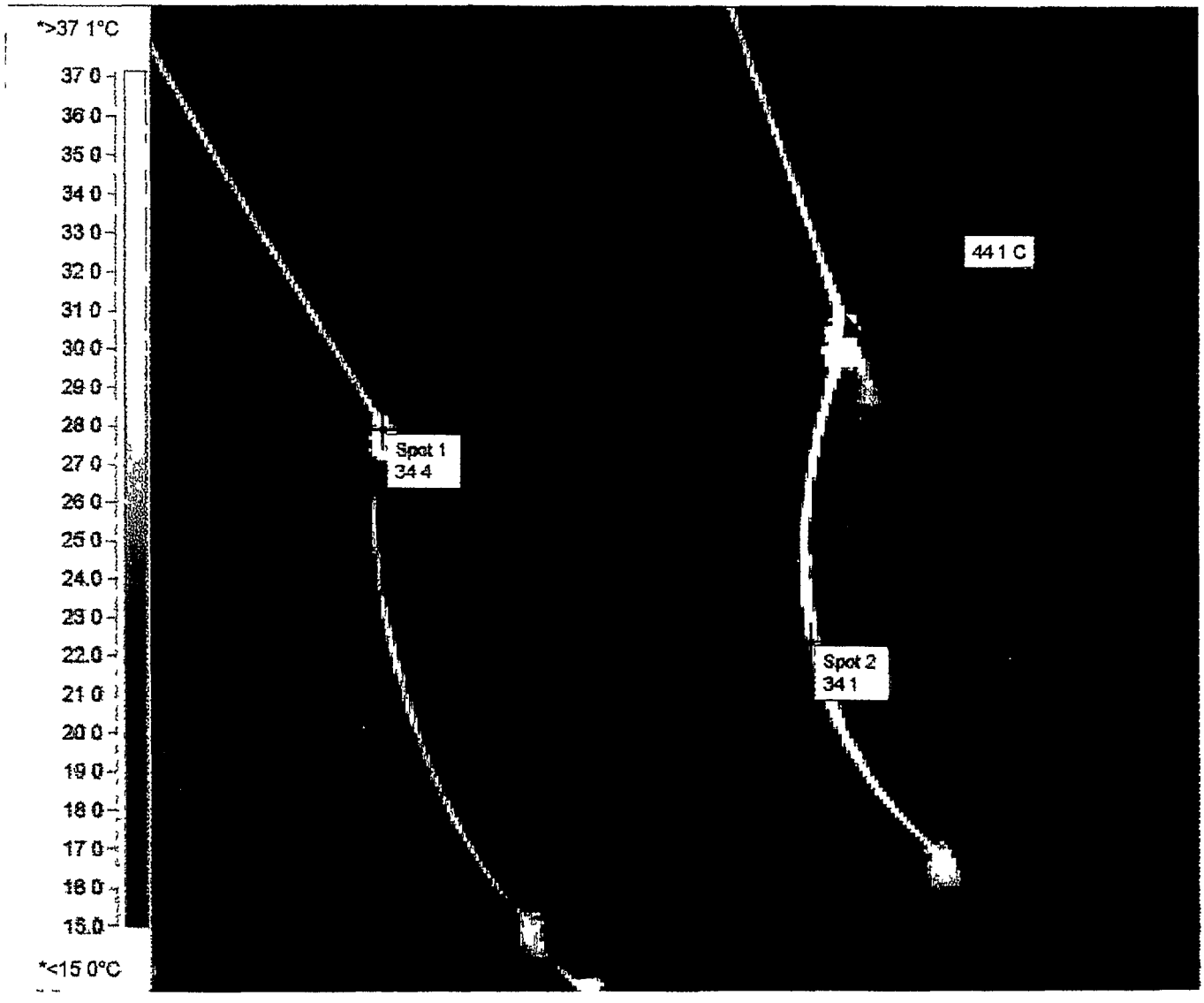
Incorrect mimic display

U/G cables not buried, but run exposed on surface

Cover plates missing from panels

132 KVA Substation,Hisar-R Phase conductor clamp

J01 TIF

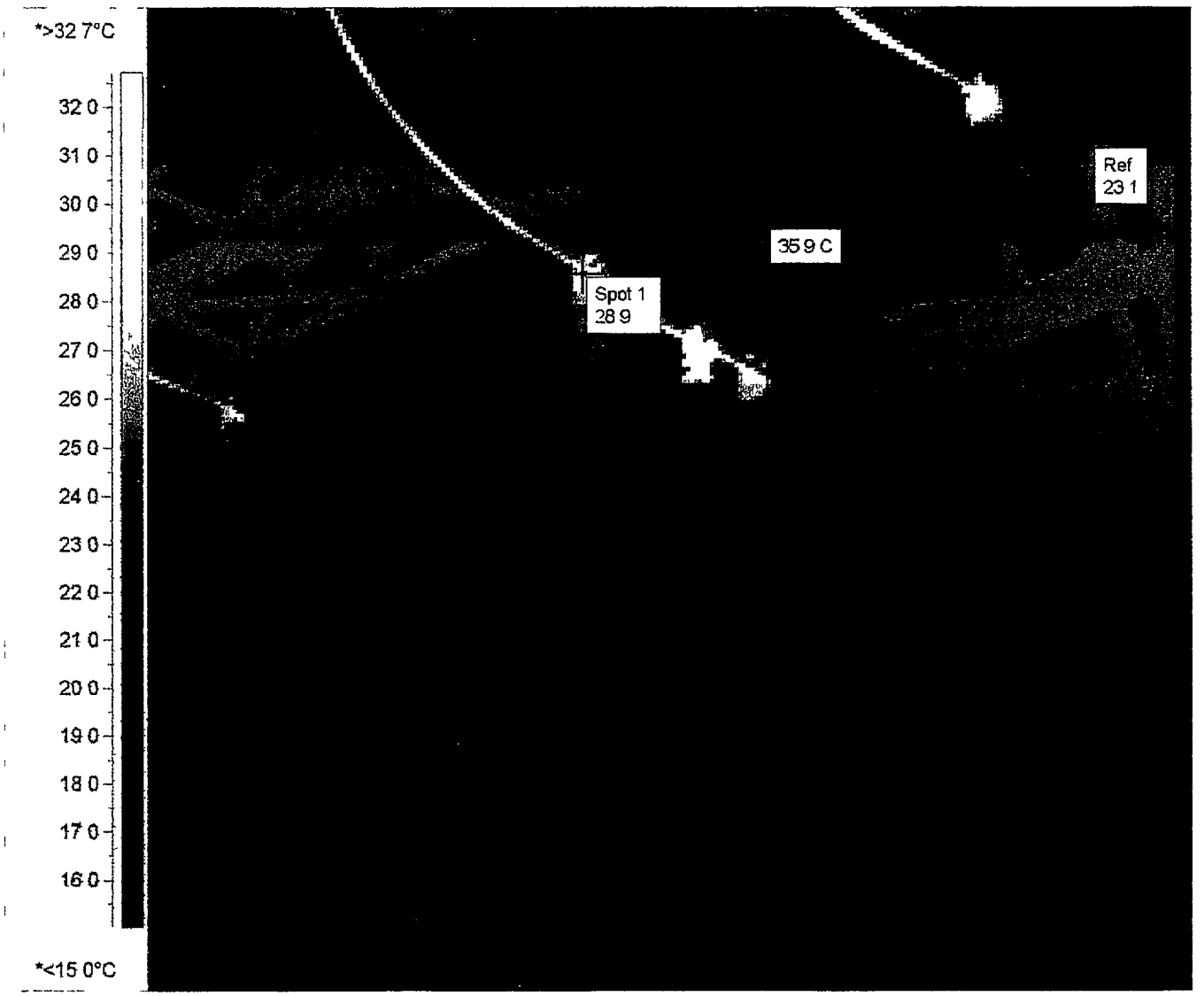


inframetrics ThermMonitor 95 12/11/98 9 46 32 AM

224

132 KVA Substation, Hisar-Middle Phase cable end connector

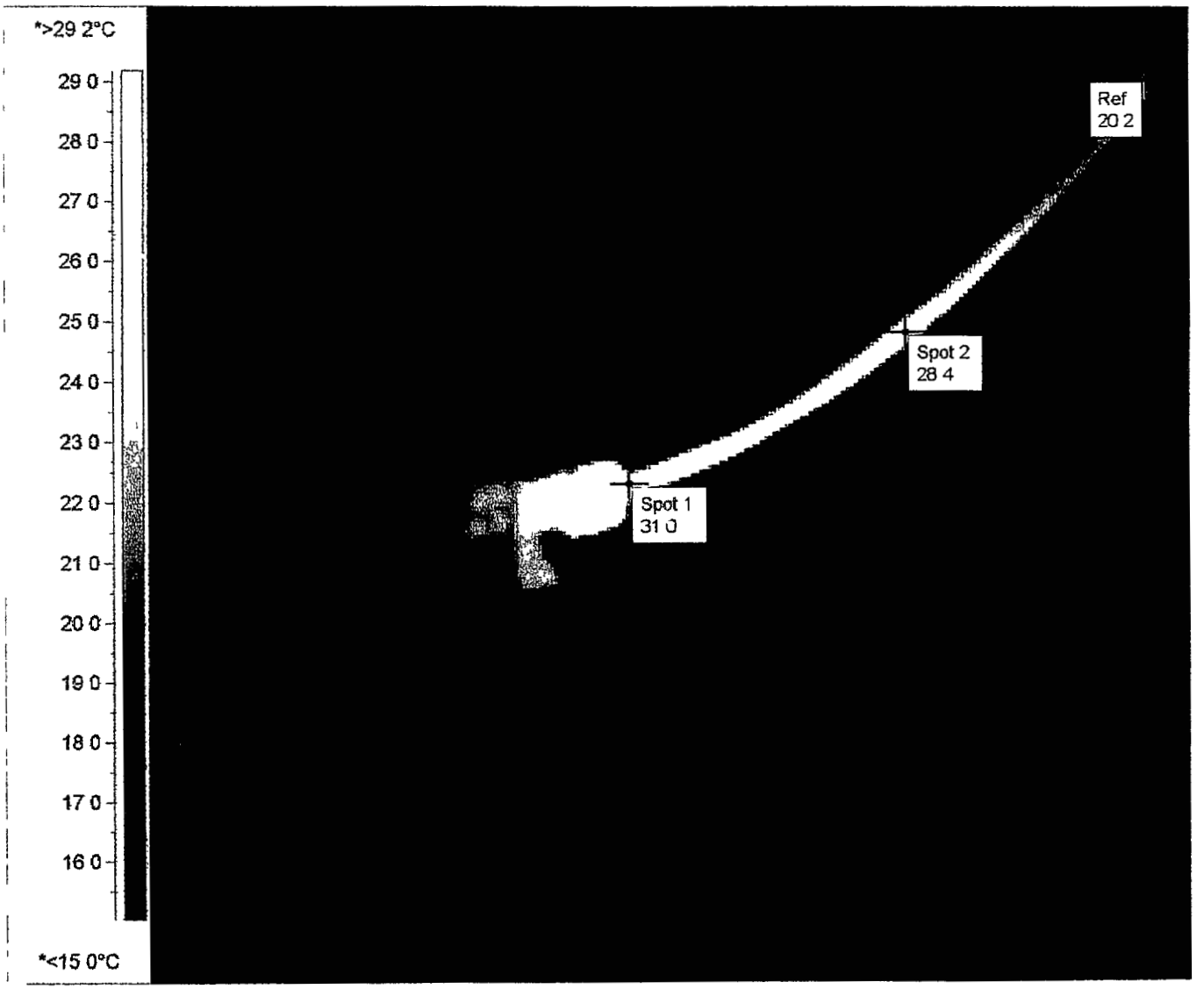
J02 TIF



inframetrics TherMonitor 95 12/11/98 9 59 35 AM

132 KVA Substation, Hisar-33 Kv R Line incoming side

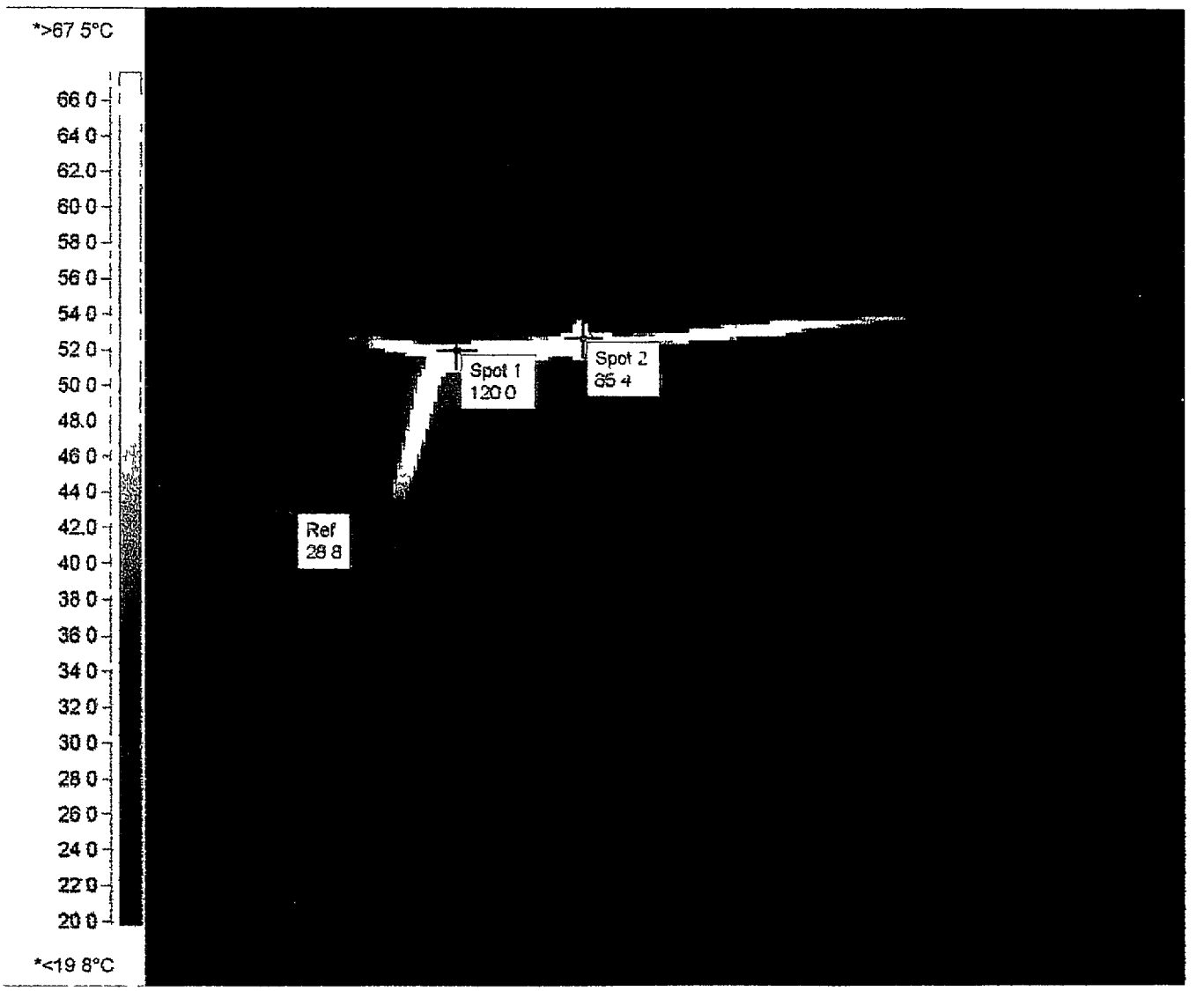
J05 TIF



inframetrics TherMonitor 95 12/11/98 10 15 16 AM

Lt cable & conductor connection, T/fr near Auto Market

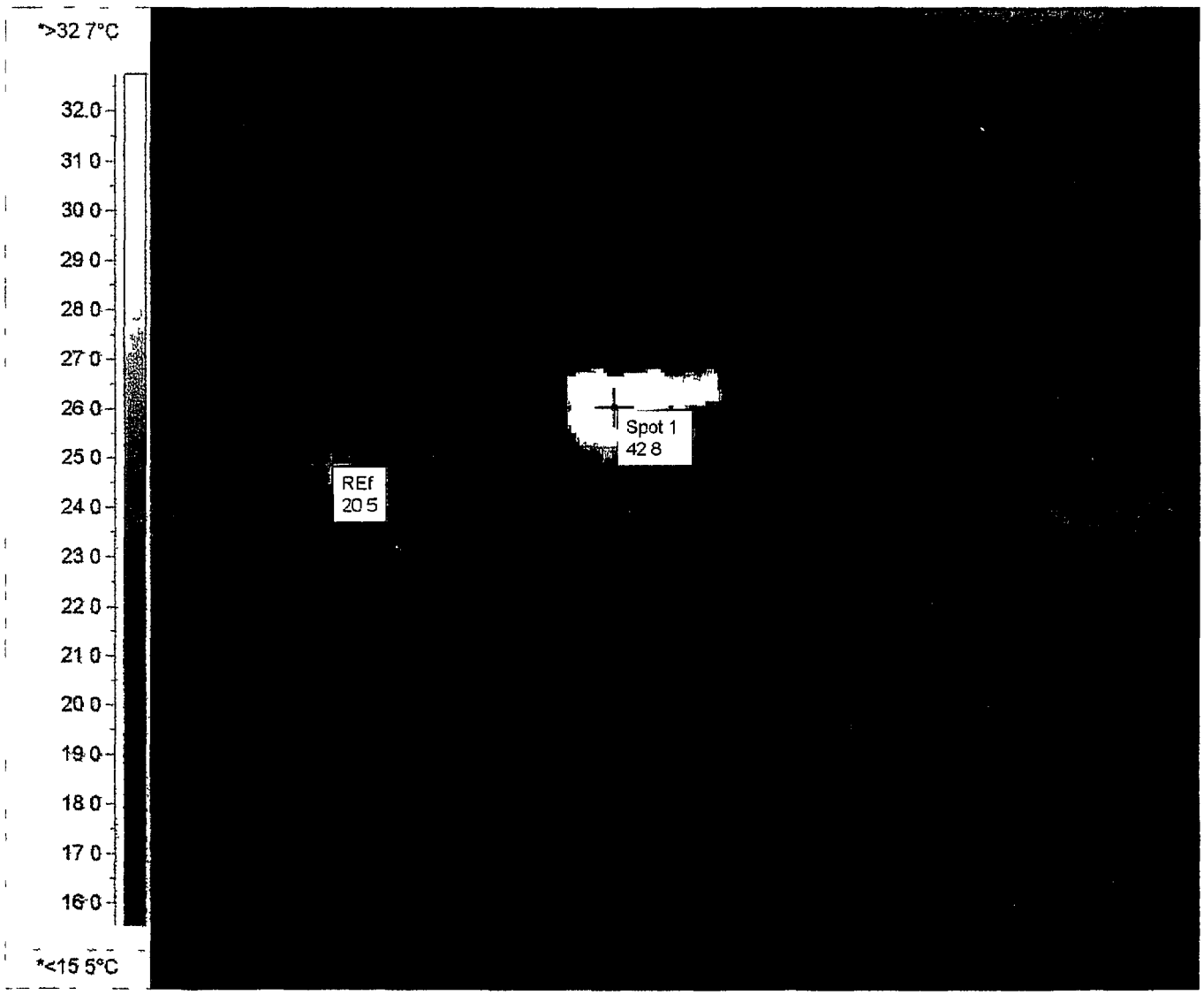
J07 TIF



inframetrics TherMonitor 95 12/11/98 10 41 24 AM

132 KVa substation,Hisar-33 Kv Isolator outside towards HTM Line

J06 TIF

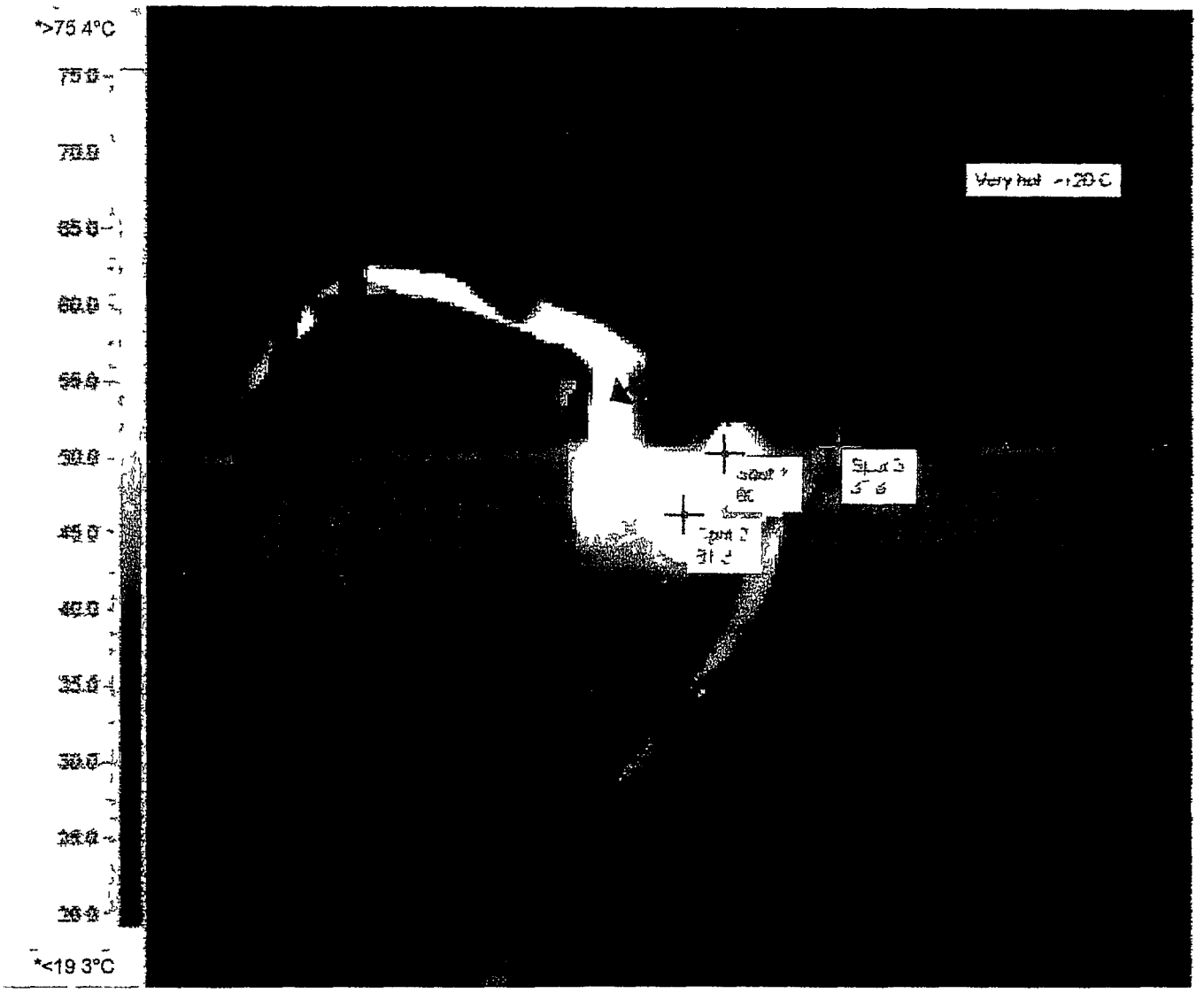


inframetrics TherMonitor 95 12/11/98 10 37 56 AM

228

T/fr 200 KVA near Old Baranala Port,Hisar

C03 TIF

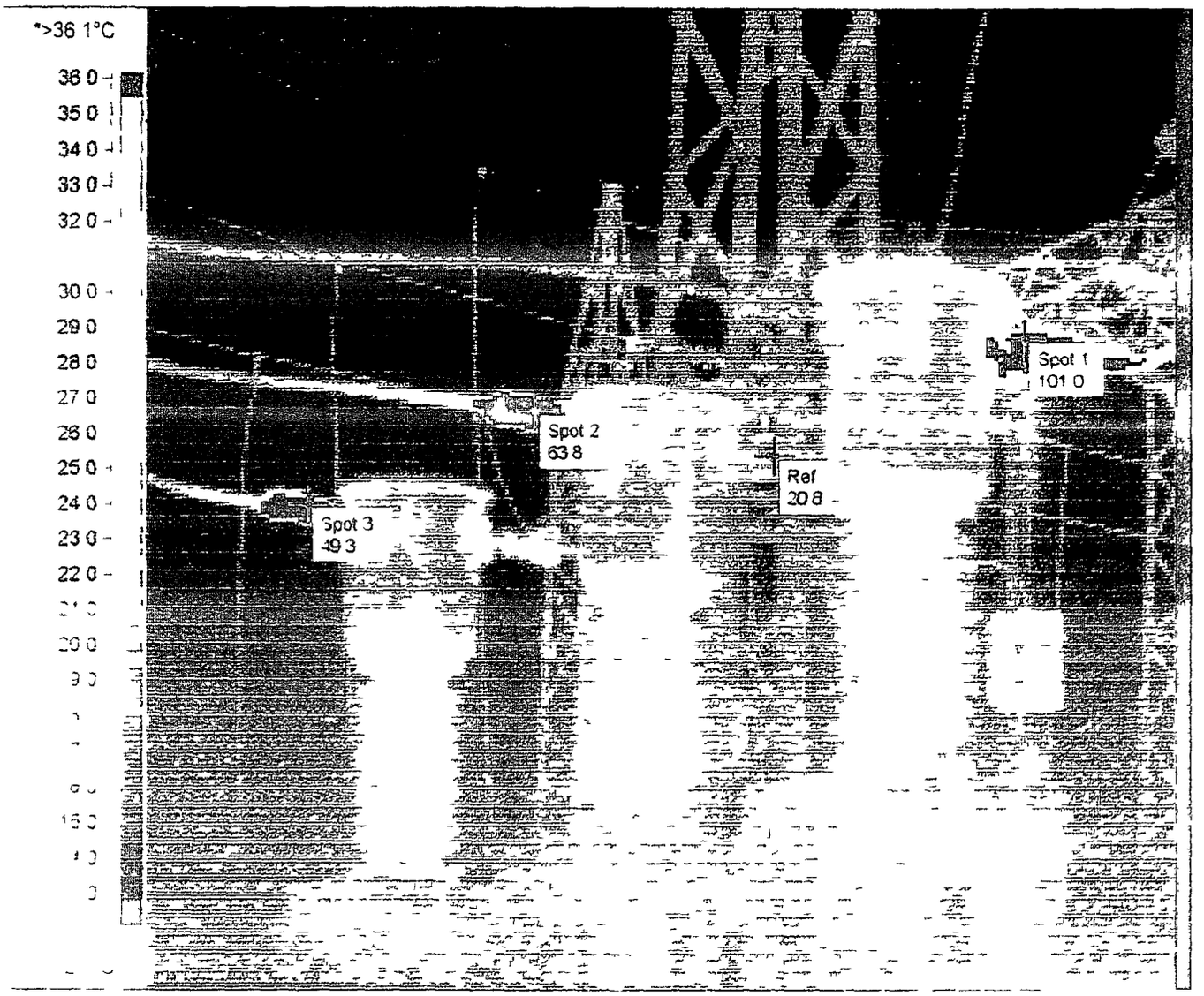


inframetrics ThermaCAM SC 12/11/98 11 43 01 AM

229

132 KVA Substation,Hisar-R,Y,B Phase CT(09 12 98)

J04 TIF

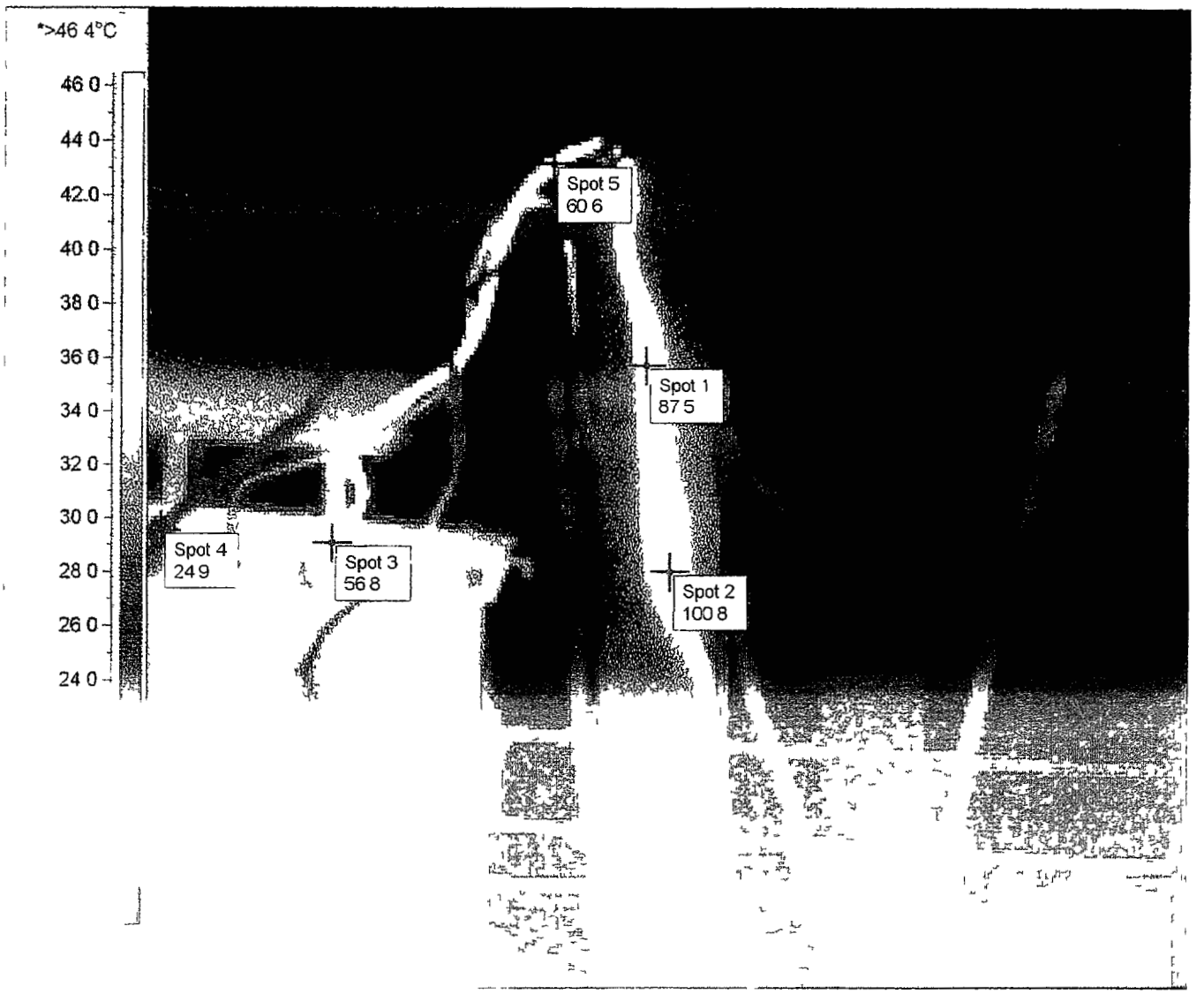


inframetrics TherMonitor 95 12/11/98 9 58 55 AM

730

Blue Phase cable from T/fr

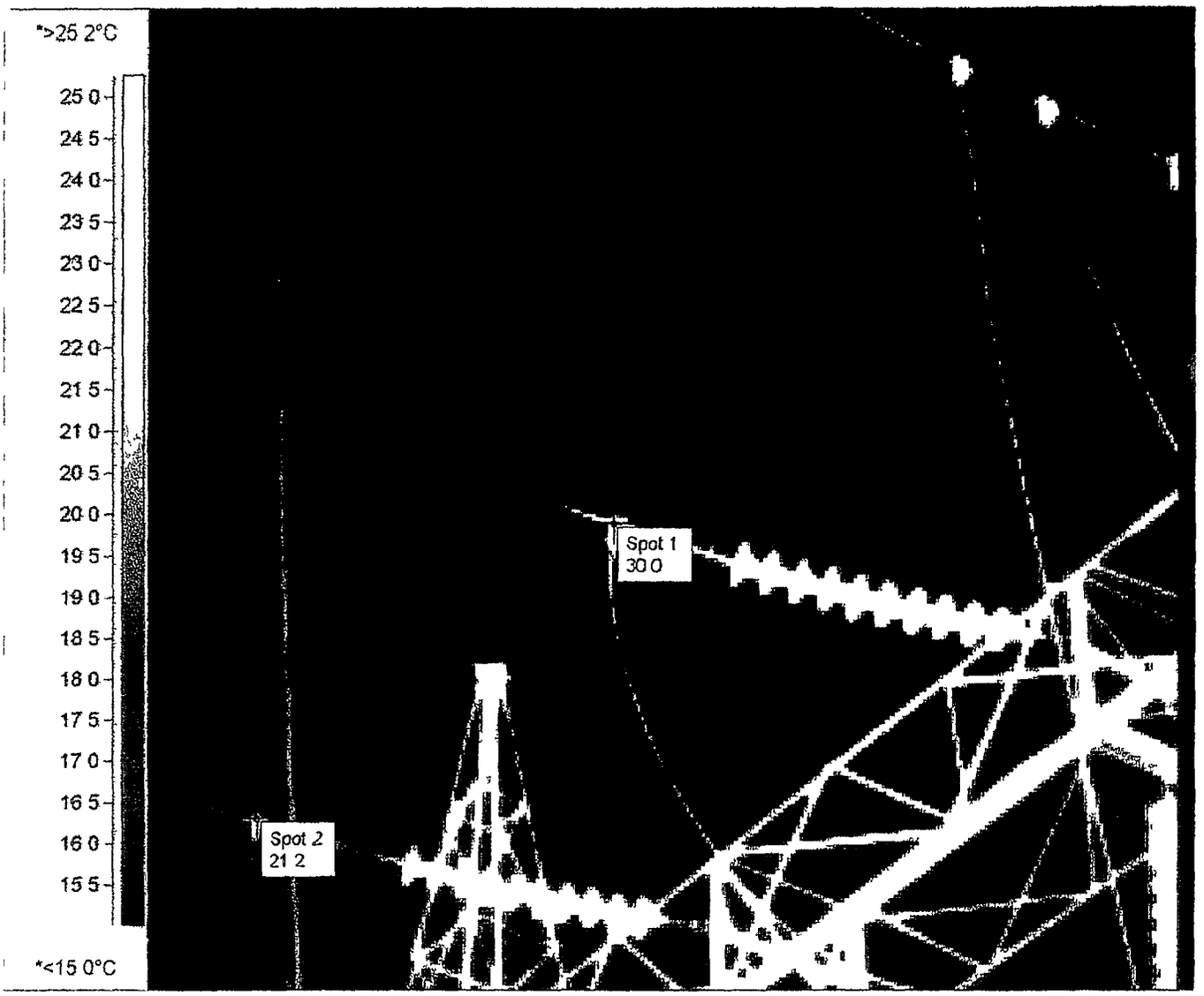
C06 TIF



inframetrics TherMonitor 95 12/11/98 4 24 21 PM

132 KV Substation,Hisar-Middle Phase 132 KV Line

C01 TIF

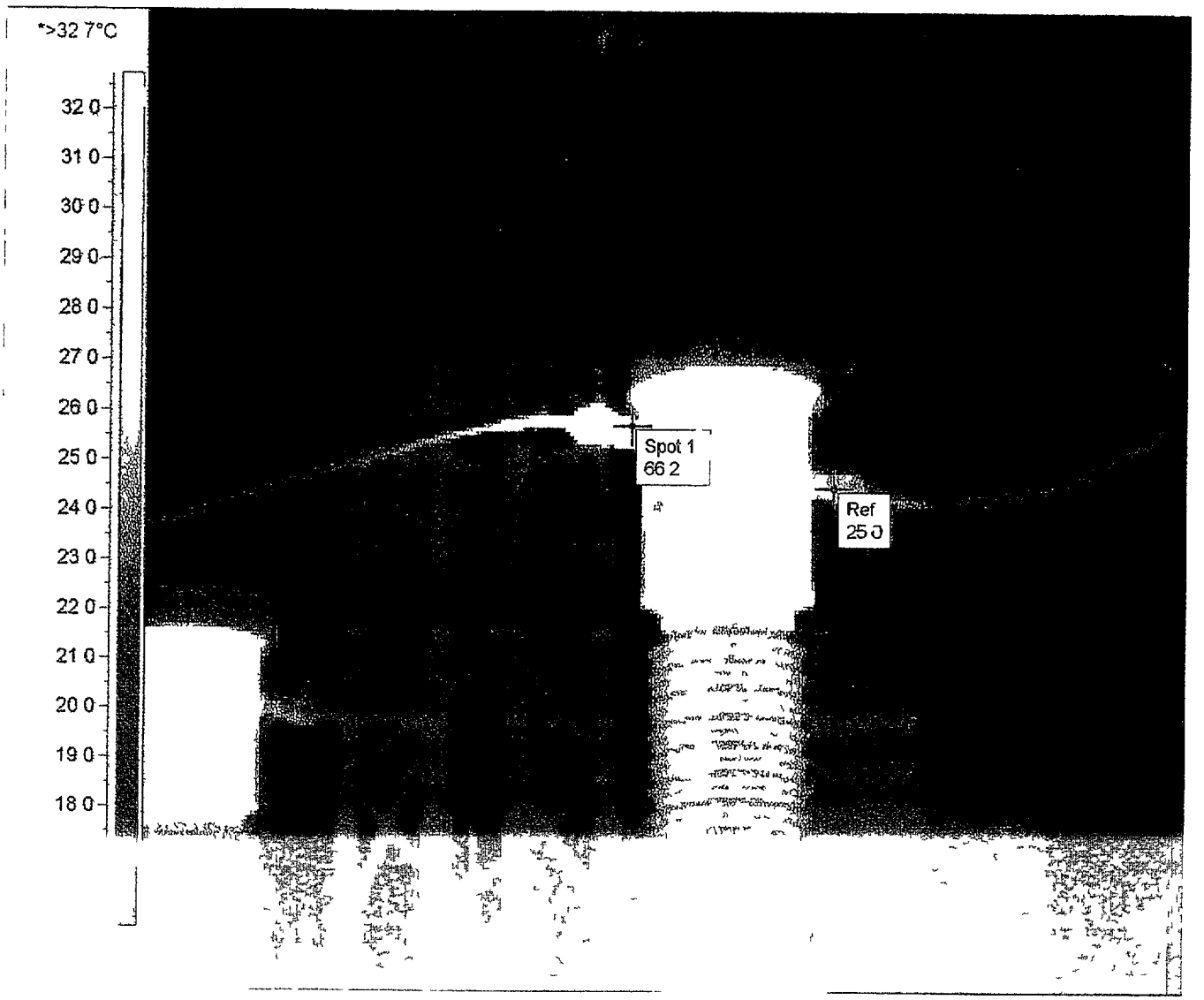


inframetrics TherMonitor 95 12/11/98 4 21 46 PM

232

132 Kv substation,Hisar-Incoming side of CT of T/fr

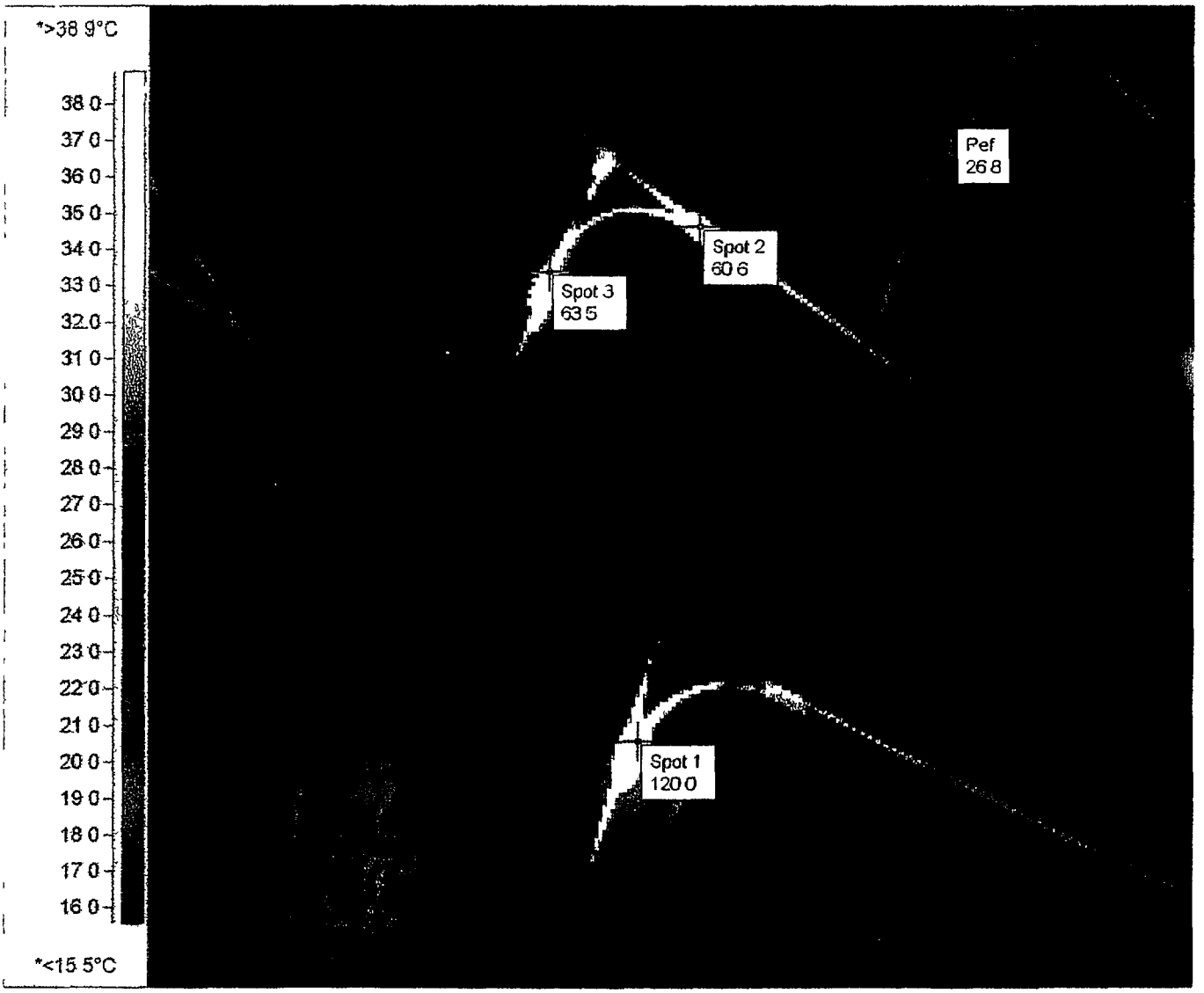
H15 TIF



inframetrics ThermMonitor 95 12/11/98 4 27 16 PM

132 Kv Substation,Hisar-First & Middle Phase PG Clamp

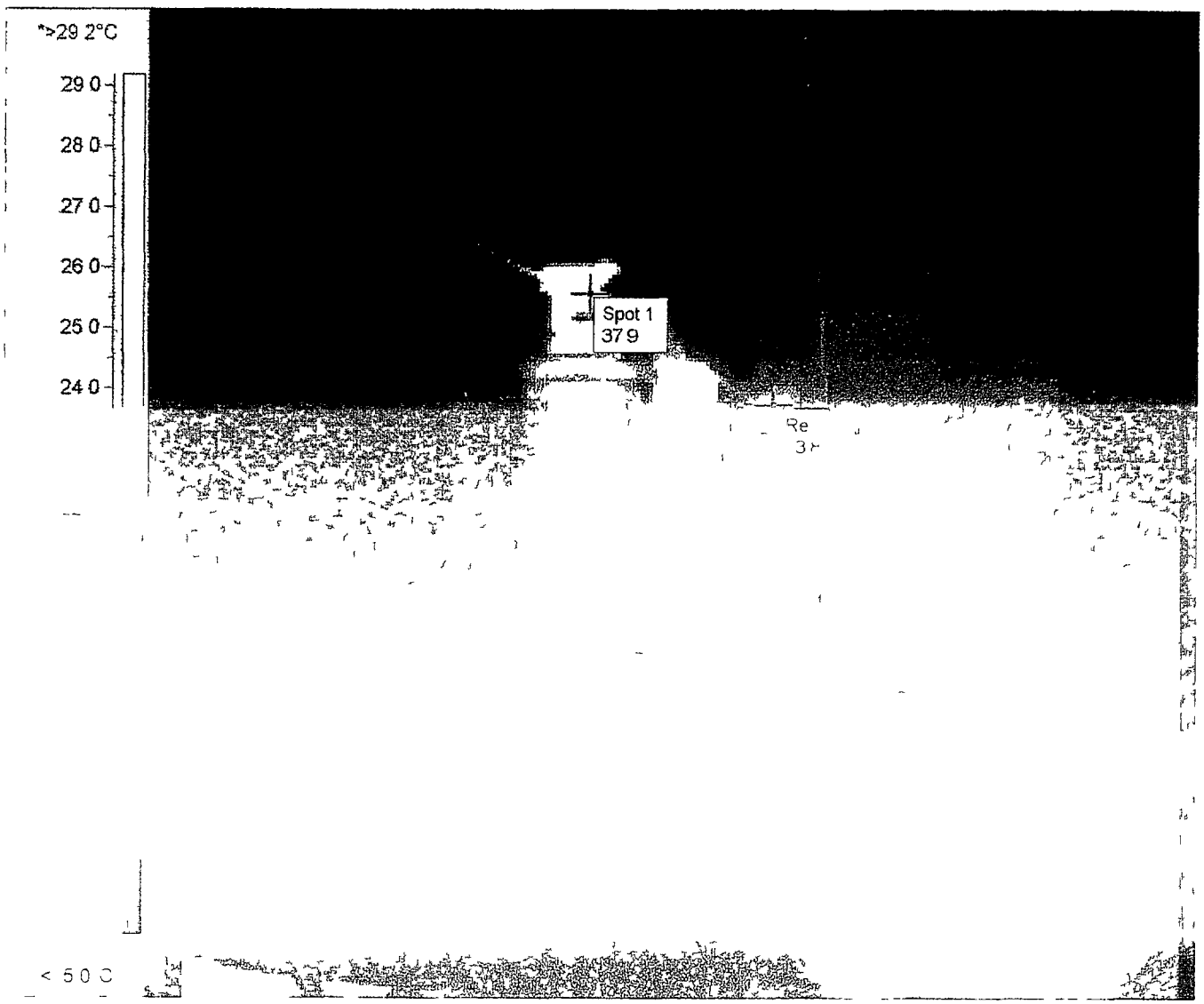
H16 TIF



inframetrics TherMonitor 95 12/11/98 4 31 04 PM

132 Kv substation,Hisar-Middle Phase Isolator Incoming

H13 TIF

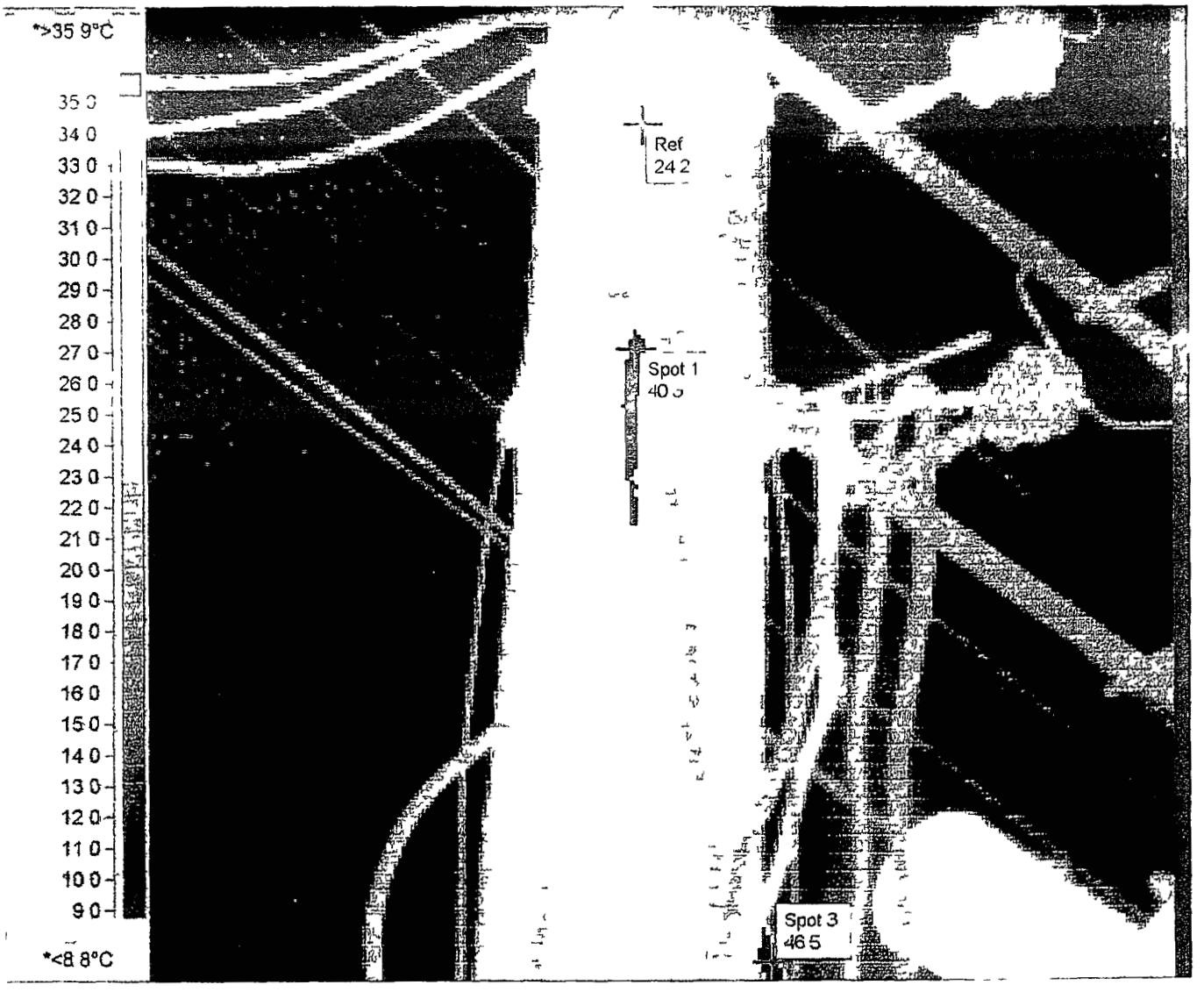


inframetrics TherMonitor 95 12/11/98 4 37 18 PM

235

H T BUSHING

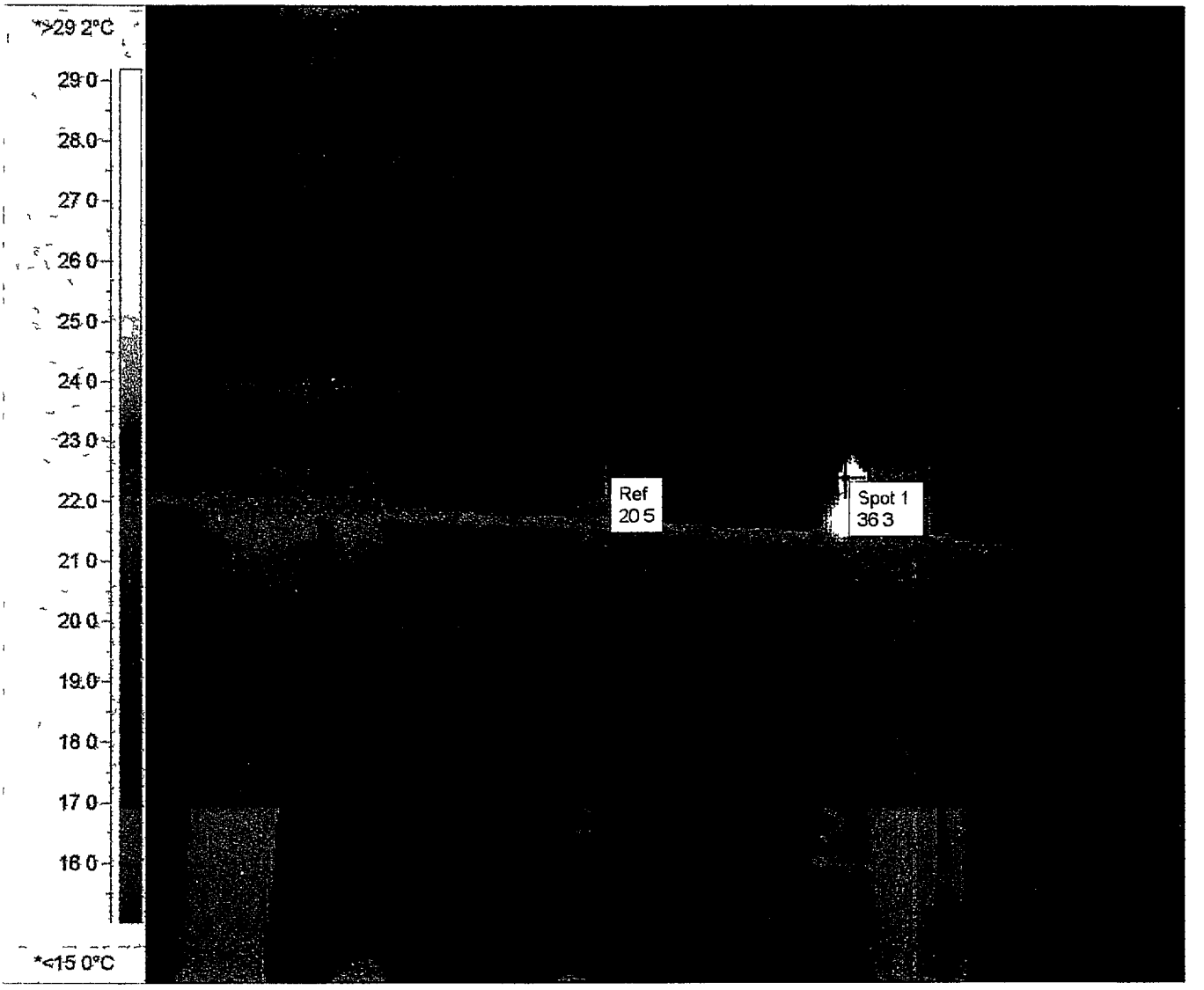
J09 TIF



inframetrics TherMonitor 95 12/11/98 11 03 23 AM

63 KVA T/fr near auto Market GO Switch

J08 TIF

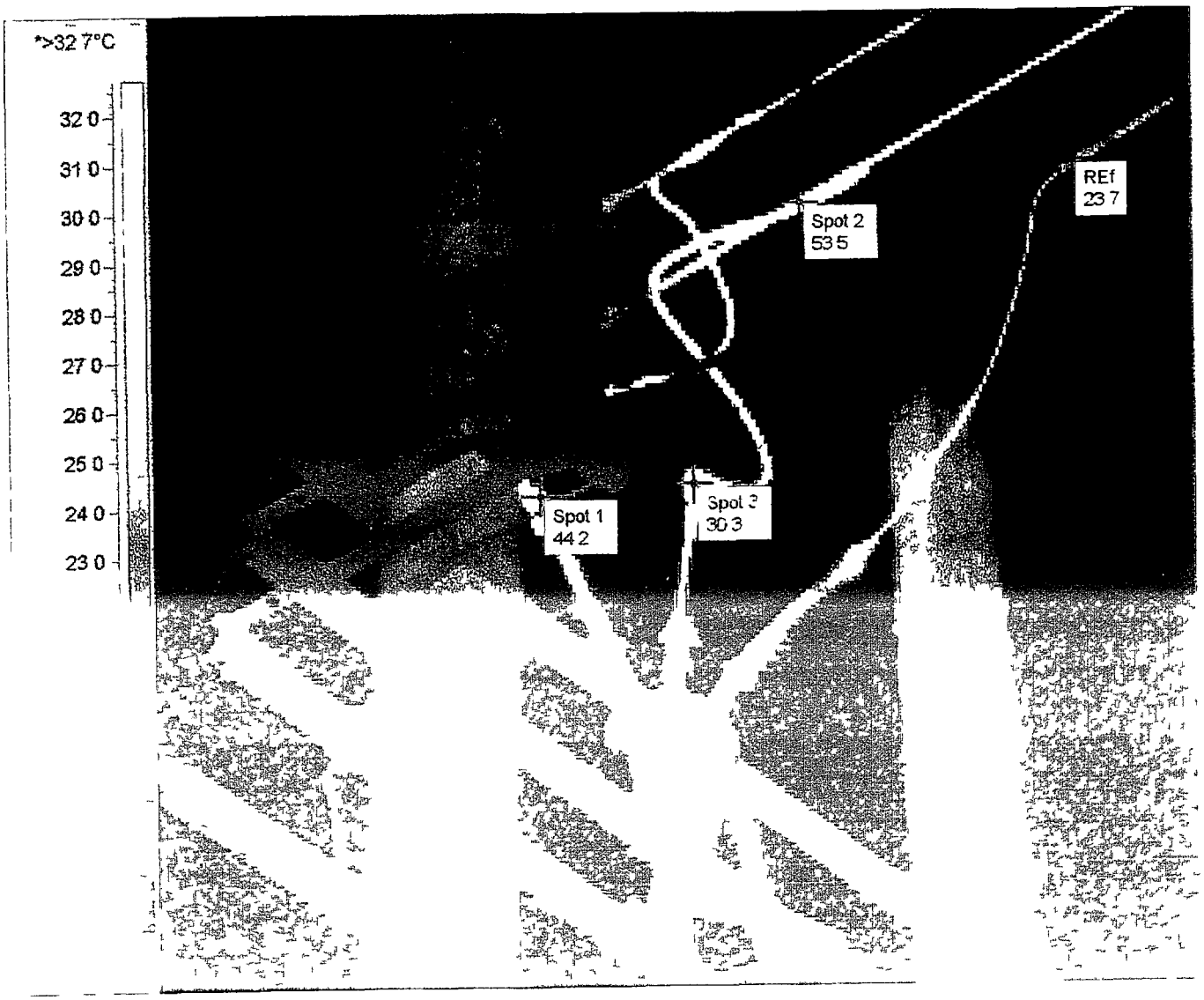


inframetrics TherMonitor 95 12/11/98 11 24 35 AM

237

Civil Hospital Middle Phasecable jumper & conductor

C02 TIF



inframetrics TherMonito 95 12/11/98 11 35 15 AM

238

APPENDIX - V

REPORTS OF INDEPENDENT IRG VISITS TO SWITCHYARDS

(i) PINJORE

(ii) MADHANPUR

(iii) BABYAL

(iv) PEHOWA

(Prior to start of Training Program)

IRG INTERNATIONAL RESOURCES GROUP

INDIA

AUGUST 1998 – SEPTEMBER 1998

10) CT ratios not marked

11) Hotspots on scanning

12) Missing and/or unconnected LA's on outgoing MV feeders

MADAN PUR S/S (220/66/11 kV) **8-28-98**

Contact Person Mr Aman Deep – SSE
Mr Rajesh Kakkar – JE

Observations (items needing investigation & correction)

1) Crushed rock of substation grounding system is still visible but overgrown weeds, thick in some areas, defeat the insulating properties of the crushed rock surface

2) HV breaker control cables are run exposed on the inverted metal channels which get heated by the mid day sun This exposure to high temperatures will accelerate the aging of these cables and cause cracking with subsequent moisture seepage into the cables

3) Field routing of control cables due to earlier modifications have shortened original cables In order to re-install these cables, short cuts have been taken in the metal cable raceways by going over the sharp metal sides of the racewavs to enable the shortened cables to reach Heavy bundles of cables resting on a sharp metal edge would cause eventual cutting of the metal through the XLPE insulation of the cables with ultimate failure of the cables

4) Rod gaps across CT's did not appear to be uniformly set

5) On all switchyard lightning arresters the combined leakage current ammeter/counter at the base of each arrester was badly corroded and non-functional Since the instrumentation is directly in the ground lead of the arrester it should be verified that corroded instrumentation has not "open circuited" this ground lead, as otherwise an "ungrounded" LA will be totally ineffective in the system

6) On 220 kV – 66 kV transformer, the oil temperature gauge reads 45°C and the winding temperature gauge reads 42°C This discrepancy was pointed out to SSE who confirmed that the winding temperature gauge had a stuck pointer and he corrected the discrepancy

7) The overhead lightning shield wire over a part of the 66 kV switchyard was missing, leaving a large area of 66 kV bus exposed with no shield wire protection

8) The 66 kV – 11 kV transformer was leaking oil at gaskets in the vicinity of the piping elbow containing the Buchholz relay A plastic bucket, hung on the piping, was collecting the leaking oil The transformer was of 1971 manufacture

9) 66 kV Bus, Capacitor Bank -

   - Some units were defective and not in the circuit
   - Fuses have been blown on some units and no replacements furnished

10) The only fire protection in the 220 kV/66kV/11kV switchyards consists of 8 bucket of sand located near the 220 kV-66 kV transformer

11) Fire protection in the control building consisted of two (2) CO_2 cylinder extinguishers

12) Multiratio CT's are furnished with 11 kV switchgear yet no indication is available to operator as to what ratio has actually been connected As such, there is not indication as to what the multiplying factor is to be used on ammeters and energy meters or what scales to read on dual scale ammeters

13) Power factor meter on the 11 kV bus reads 0 7 lead @ 11 kV, with capacitor bank not connected to 11 kV system The meter was obviously defective

BABYAL S/S (66/11KV) 9-3-98

(Contact Person Mr R.K Diwan – Station Operator)

Observations (Items needing investigation and correction)

1) Two (2) incoming 66 kV lines but only one half of the 66 kV substation is operational Equipment has been cannibalized from the defective half to supplement the operational half

2) Only one (1) 66 kV – 11 kV transformer is available No back-up or standby transformer or circuits available

3) Eight (8) 11 kV outgoing feeders in service Two (2) important feeds to the "armed forces offices" are important so much so, that there is a standby 11 kV feeders available if one of the two regular feeders fail Yet no backup at the 66 kV level

4) Incoming 66 kV circuit has only one single phase CVT on blue phase of incoming line No CVT on either red or yellow phases at 66 kV (also, no CVT's at all on 66 kV circuit No 2)

5) No wave traps on 66 kV ckt-1 (2 wave traps on 66 kV ckt-2 but neither on is connected)

6) All 66 kV isolators can only be manually operated Electrical operation is non-functional All auxiliary contacts on isolators are corroded and seized up and are non-functional

7) No LA's on incoming 66 kV lines Only rod gaps have been provided across the insulators of the line isolators Settings appear to be erratic

8) Incoming 66 kV line has a 66 kV circuit breakers as the only isolation means between incoming 66 kV line and the 66 kV-11kV transformer

   This breaker consisting of single pole ganged interrupters has the blue phase bussed across its interrupter with only the Red and Yellow phases going through their interrupters The breaker therefore can never be used to isolate a fault on the blue phase

   Further, the way the HVPNL operators isolate the power transformer from the system, under normal conditions, is to trip the 11 kV load on the transformer secondary, then open the red and yellow phases of the 66 kV breaker, and then operate the line disconnects of the 3-phase 66 kV line isolator The 66 kV disconnect in the blue phase would thus still be interrupting the magnetizing current of the power transformer These isolators are not load or magnetizing current break switches

9) The counters/ leakage current ammeters on all 66 kV lightning arresters are corroded and non functional As they are in the ground lead of the arresters, a check should be

made to ensure that the LA's are still adequately connected to the ground grid and are not 'open circuited' in the instrument box

10) The single power transformer runs fully loaded (above its OA rating) 24 hours a day and the fans run continuously This again points to the critical situation here of no backup power if any one component on the 66 kV side fails

11) The tap-changer on this power transformer is an on-load tap changer However, the taps are only changed manually and only by de-energizing the transformer, by the operator The ON-LOAD feature of tap changer is non-operational

12) Two parallel cable circuits are connected to the 11 kV bushings of the power transformer One circuit is a (1) – 3/C PILCA cable with (3) well spaced stress cones on a single trifurcator box The other circuit is (3) – 1/C XLPE cables with an individual stress cone on each cable The line side of the stress cones on the blue and yellow phases are physically too close together (about 6-7 inches) This spacing should at least be increased to 9 inches minimum by using an appropriate spacer to keep the line side of the stress cones apart

13) Oil level on the conservator tank of the power transformer was between ¼ and ½ full

14) Fire protection system for the entire switchyard consisted of 5 buckets of sand The sand in some buckets was caked, as water had got into the buckets at an earlier time (probably rain water) When required in an emergency this sand would probably not pour out easily to extinguish an arc or flame

15) Fire protection system inside the control building consisted of (2) two CO_2 portable cylinder type extinguishers

16) The original crushed rock surface laid in the switchyard for limiting the lethal voltages and currents to operators, during faults, has sunk into the soil There is no continuous crushed rock surface in the switchyard

17) Overgrowth of weeds in the switchyard further compounds the danger operators are exposed to, by reducing the insulating quality of the 'crushed rock' surface

18) Only one 11 kV capacitor bank was operational This bank appeared to be intact, with all fuses intact, and all units in service

19) All indicating lights on all the 11 kV switchgear panels and 66 kV control panesl are not operational Therefore any information available to operators from the status of the indicating lights is non existent Other secondary means have to be resorted to, to determine the condition of circuits and systems Feeder ammeters and breaker mechanical flags have to be relied on to indicate to an operator whether the circuit is alive or not

20) Many breaker mechanical targets are bent, broken or missing

21) A few ammeters are non-operational

22) Connected ratios of CT's are not available to the operator, so that instrument multiplying factors are not available, or readings of dual scaled ammeters are not known

23) The PILCA (1)-3/C incoming cable to the 11 kV switchgear is weeping oil at the gland

24) The bare minimum of staff available at the substation only perform switching operations and do not carry out any substation maintenance

25) The 11 kV bus coupler between the 2 sets of 11 kV switchgears consists of a permanently closed 11 kV breaker There are no overcurrent protective relays for this breaker or no control switch The breaker operates as a permanently closed link

26) None of the semaphores are indicating lights on the 66 kV mimic bus control panels are working

27) The defective 66 kV breaker in the switchyard has a non-operable control switch on the 66 kV control panel The electrical control of the breaker is non operational The station operator informed me that the breaker charging motor was defective so that the breaker could not be operated electrically The breaker can be only opened or closed [only red & yellow phases – see item (8) above] by operating the local manual pushbuttons at the breaker itself The breaker has to be charged with the manually operated charging handle

The above leads to a very unsafe scenario The power transformer if it develops a fault will cause it's differential relay to operate which will attempt to isolate the faulty transformer by opening the 11 kV low side breaker and the 66 kV high side breaker Since the high side breaker has no electrical control, the breaker will not trip and the 66 kV line will continue to feed the fault It is highly unlikely that the line breakers at the sending end of the 66 kV line will see this transformer fault even with delayed tripping The transformer will eventually be destroyed This is a highly dangerous situation

28) The ammeter indicating the load being furnished by the main DC distribution panel breaker, is non-operative

29) Outgoing 11 kV feeders -

The LA's on the H-terminal structures are not all connected to the outgoing overhead lines Some have open circuited phase connections

30) The 11 kV cable which comes from the 11 kV switchgear to the H-structure has an ungrounded armoring at the pothead

31) Isolator disconnect switches on the H-structures are non-operational, yet they are left in the circuits No correctly chosen connectors are in use to make all the connections from isolator terminals to the overhead lines, arresters and other equipment Improvised field wire wraps take the place of correctly chosen connectors Redundant

equipment, incorrect connectors, all lead to high losses being generated at these H-terminal structures

32) There was no main annunciator panel in the control building No indicating lights functioned

33) No evidence found of

(a) Feeder and transformer load logs

(b) Battery specific gravity logs

(c) Substation ground grid resistance logs

(d) Log of outages or line disturbances

(e) Logs of non-operational equipment

34) It appeared that the meagre staffing at the substation enabled the operators to only devote their time to system operation with little or no time available for routine maintenance

35) It also appeared that the operators had no access to spare parts such as indicating light bulbs, etc and as such, replacements were never carried out

36) Major equipment replacements -

There appeared to be no system for reporting these deficiencies and no procedure whereby dangerous situations could be avoided by the timely replacement of defective and faulty equipment

PEHOWA S/S (220/132/33 11 kV) **9/4/98**

(Contact Person
Mr Ashok Kumar Sehgal, Asst Engineer, Operations)

Observations (Items needing investigation and correction)

1) The 132 kV LA's, on the low side of the 220-132 kV autotransformers have corroded, non-functioning, leakage current ammeters/surge counters
2) One portable CO_2 cylinder type extinguisher had been left at the 220-132 kV transformer T2 Transformer T1 had no visible fire protection system
3) The cables leaving the control cabinet of the OLTC mechanism of tranformer T2 were not sealed In my presence, a squirrel ran up the cables and into the control kiosk, and had made his home in it There was no sealing gland to prevent this happening Rodents could also chew through the cables and cause problems
4) The 11 kV feeders leaving the switchyard were all on H-concrete pole structures The stays at the opposite side of the line conductors were not tensioned and in some cases broken, and the H-structures leaned very heavily into the lines
5) The oil level on the conservator tank of the 132-11 kV power transformer T3 was between the ¼ and ½ full mark
6) The oil cup on the silica gel breather of the 132-11 kV transformer T3 was missing
7) Transformers T3,T4,T5,T6,T7 and T8 had one portable CO_2 extinguisher per transformer, and six sand buckets to serve each pair of transformers This was the only fire protection system for this line up of (2) 132-11kV and (4) 132-33 kV transformers
8) 132-33 kV transformer T5 did not have it's measured impedance stamped on it's nameplate
9) 33 kV LA's were not located at the 33 kV bushings of the 132-33 kV transformers ,but rather they were located across the roadway and at the 33 kV bus
10) 33 kV capacitor bank has fuses blown on some units, and on different phases
11) Outgoing 11 kV and 33 kV overhead feeders appear to have an isolator switch in each 3-phase circuit which when manually operated at peak load periods, opened one-phase of the circuit This was to deliberately load shed customers at peak load periods Unbalanced loads like this could cause higher losses due to unbalanced currents flowing in neutrals causing additional copper losses
12) The main station battery had no fuses at the battery on the cables leaving the battery to the main breaker of the DC distribution panel A fault in this cable could burn out the battery This station has no standby DC source to this single 220 V dc battery supply
13) Logs of battery specific gravity were apparently being taken on a weekly basis This was not verifiable
14) 33 kV relay panels -

    Semaphores were not working
    No p f meter was on the panels to indicate how the capacitor bank operated
    Instructions had been given to the operators to "switch on capacitor bank when load is 100-150 amps "

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15) 132 kV relay panels -

During the inspection, the 132 kV system voltage read 120 kV Upon inquiring why this was so low the operator cranked up the voltage by manually operating the ON LOAD tap changer of the 220 – 132 kV transformer from about tap 12 to about tap 7

The 132 kV system frequency as indicated on the panel was 51 5 Hz

16) 220 kV relay panels -

A cutout in one of the relay panels had no metal cover plate over it A piece of paper had been pasted over the opening to hide the live terminals from view and a large hole had torn the paper, exposing the cable terminations within the cabinet

APPENDIX - VI

INSPECTION CHECK LIST FOR WALKDOWNS

(Prepared for Training Program)

IRG INTERNATIONAL RESOURCES GROUP

INDIA

AUGUST 1998

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SWITCHYARD, SUBSTATION AND FEEDER INSPECTION CHECKLIST

The following is a checklist of the System Efficiency Improvement On-The-Job Training Program The checklist includes items that will be covered during the visit to the various substations It is intended that this be used as a guide by the participants to identify what to look for when searching for the deficiencies that affect the optimum substation operation

The participants are encouraged to continue self-research activities to become proficient at each of the subjects covered during the performance of the training program
The participants are also encouraged to actively participate in the program by asking question, expressing and finding solutions to problems that affect their own substations and power distribution systems

SEI TRAINING PROGRAM

SWITCHYARDS, SUBSTATIONS, AND FEEDERS CHECKLIST

INSPECTION DATE / / **TRAINEE NAME**

COMPONENT NAME OR CHECK TO BE PERFORMED	COMPONENT STATUS	
	OK	CORRECTIVE ACTION
A HV/MV SWITCHYARD		
1 Review Equipment One-Line Diagrams		
2 Review System Protection and Metering One Line Diagrams		
3 Inspect Switchyard Facilities		
a Incoming HV Gantry Towers		
b HV Line Terminations		
i Isolators and Grounding		
ii Wave Traps		
iii Coupling Capacitor Potential Devices		
iv Lightning Arresters		
v Circuit Breakers		
vi Current Transformers		
c HV Bussing		
i Configuration		
ii Isolators		
iii Circuit Breakers		
iv Lightning Arresters		
v Current Transformers		
vi Potential Transformers		
d Power Transformers		
i Name Plate Data		
◆ Impedance		
◆ MVA Ratings		
◆ Vector Grouping		

COMPONENT NAME OR CHECK TO BE PERFORMED	COMPONENT STATUS	
	OK	CORRECTIVE ACTION
ii Cooling Systems		
♦ Natural Air (OA)		
♦ Fan Cooling (FA)		
♦ Oil Cooling (FOA)		
iii Lightning Arresters		
iv Oil Catch Pits		
v Bucholz Relays and Conservator Tanks		
vi Temperature Indicators and Alarms		
vii Oil Level Indicators and Alarms		
viii Silica Gel Breathers & Oil Cups		
ix Tank Condition (Rust, Oil Leaks)		
x Radiators (Oil Leaks)		
xi Tank Grounding (2 grounds)		
xii Neutral Grouding and Neutral Grounding CT's		
xiii Terminations		
xiv Fire Protection Systems		
xv Firewalls and/or Spacing Between Transformers		
e Medium Voltage Switchyards		
i Bus Structures and Busbars		
ii Cables and Terminations		
iii Equipment Terminations		
iv Current Transformers		
v Potential Transformers		
vi Clearances		
vii Bus and Feeder Configurations		
viii Circuit Breakers		
ix Lightning Arresters		

COMPONENT NAME OR CHECK TO BE PERFORMED	COMPONENT STATUS	
	OK	CORRECTIVE ACTION
f Switchyard Grounding		
i Equipment Grounds		
ii OH Lightning Shield Wires		
iii Neutral Grounds		
iv Lightning Arresters Grounds and Surge Counters/Ammeters		
v Grounding Grid Resistance Logs		
vi Site Condition of 6" Crushed Rock Insulation Layer		
g General		
i Cable Installation and Trenches		
ii Direct Buried Cable Installation		
iii Cable Used versus Application		
iv Safety Clearances		
v Working Clearances		
vi Marshalling Kiosks		
4 Utilize Infrared Camera to Detect Hot Spots		
a Connectors		
b Equipment		
c Jumpers		
d Ground Wires		
e Cable Potheads		
f Transformers		
g Circuit Breakers		
h Isolator Switches		

COMPONENT NAME OR CHECK TO BE PERFORMED	COMPONENT STATUS	
	OK	CORRECTIVE ACTION
B METAL-CLAD SWITCHGEAR		
1 Review Equipment One-Line Diagram		
2 Review System Protection and Metering One-Line Diagram		
3 Inspect Metal-Clad Switchgear Facilities		
a Mimic Diagrams		
b Control Philosophy		
c Indicating Lights, Operation and Test		
d Metering and Instrumentation		
e Relay Settings		
f Current and Potential Transformers (Ratios, accuracy, overlapping zones)		
g Transformer and Feeder Voltages and Loading		
h Substation and Feeder Power Factor		
i Equipment Short Circuit and Continuous Current Capability		
j Cable Terminations		
k Connected Equipment Not in Use		
l Open Current Transformers, if any		
C CONTROL BUILDING AUXILIARIES		
1 Inspect Batteries and Battery Chargers		
2 Alarms Annunciated on Battery System		
3 Auxiliary Station Service Switchgear and AC Panel		
4 DC Distribution Panels		
5 Annunciator System and Alarm Philosophy		
6 HV Relay and Control Panels		
a Relay Settings and Flags		
b Maintenance and Housekeeping Practices		
c HV Mimic Bus and Control Panels		
d Semaphores, Lights and Indicating Meters		
e Color Coding of Mimic Bus		
7 Equipment Working Clearances		
8 Alarm Circuits Operation and Maintenance		
9 Emergency Lighting and Power		
10 Fire Protection Systems		

COMPONENT NAME OR CHECK TO BE PERFORMED	COMPONENT STATUS	
	OK	CORRECTIVE ACTION
D MV FEEDERS		
1 Determine Magnitude and Time of Peak Loads		
2 Distribution Transformers and Feeders Protection		
3 Distribution and Substation Class Arresters (Correct Application)		
4 Distribution Transformers Fusing (Type, Size, Configuration)		
5 Conductor and/or Cable Sizes Used on Distribution Transformers		
6 Distribution Substation Grounding		
7 Three Phase Feeder Unbalanced Loading		
8 Ground Fault Settings		
9 Branch Circuit Fusing		
10 Connectors Used on All Equipment		
11 OH Conductor Material Used and Material of All Equipment Connection Terminals		
12 Capacitors		
a Location		
b Installation		
c Protection		
d KVAr Ratings		
e Grounding		
13 Distribution System Construction and Installation Practice		
a Concrete Structures		
b Crossarms		
c OH Shield Wires		
d Grounding		
e Hardware		
f Connectors		
g Safety Clearances		
14 Take Voltage Readings Along The Line		
15 Check Jumper Wire Size		

COMPONENT NAME OR CHECK TO BE PERFORMED		COMPONENT STATUS	
		OK	CORRECTIVE ACTION
16	Scan for Hot Spots		
a	Connectors		
b	Jumpers		
c	Transformers		
d	Fuse Cutouts		
e	Isolators		
f	Capacitors		
17	Evaluate Scanning Results		

APPENDIX - VII

HVPNL - INTERFACING PERSONNEL, SELECTED SWITCHYARDS, SCHEDULES, AND LIST OF TRAINEES

(During Training Program)

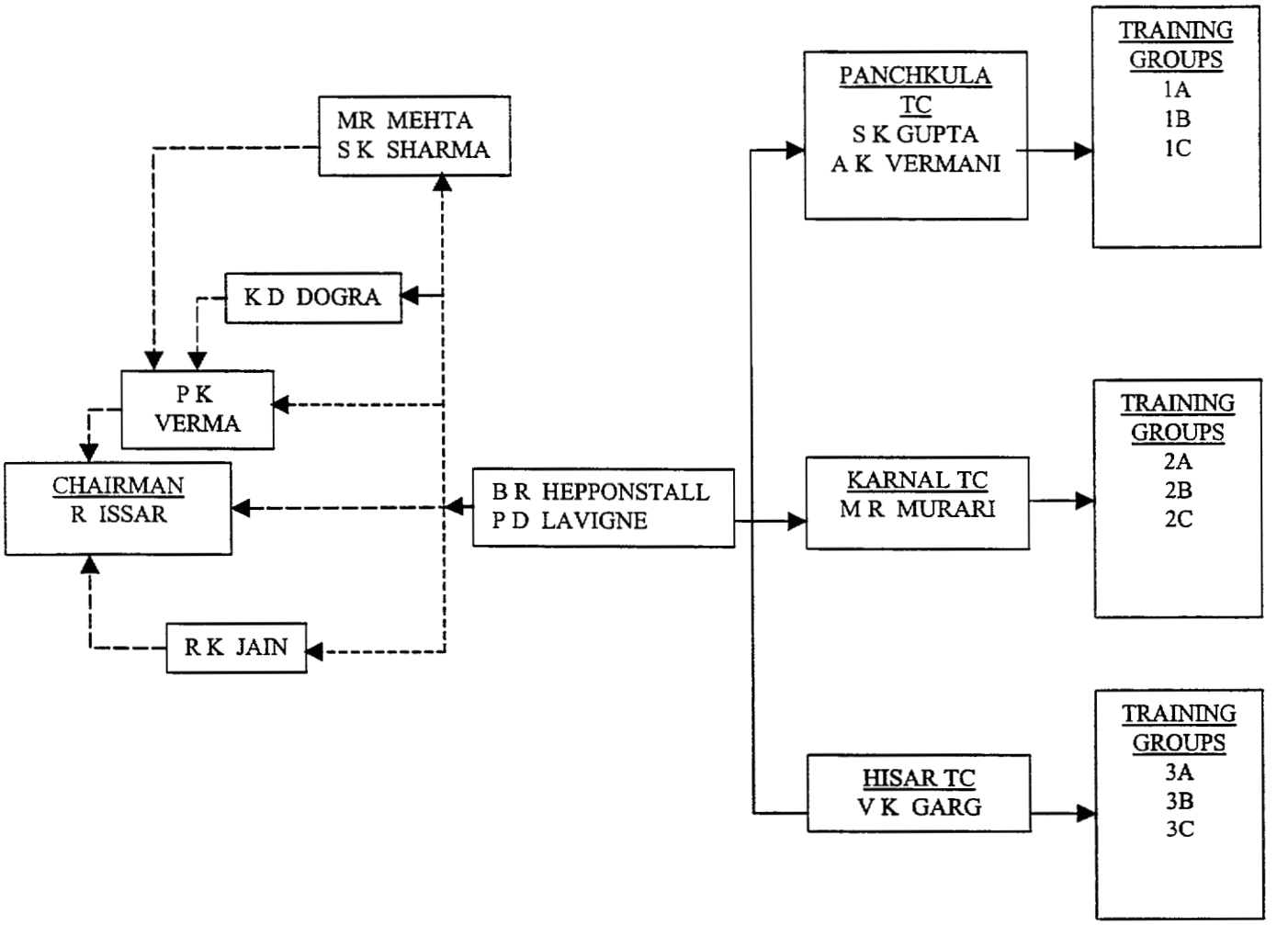
IRG INTERNATIONAL RESOURCES GROUP

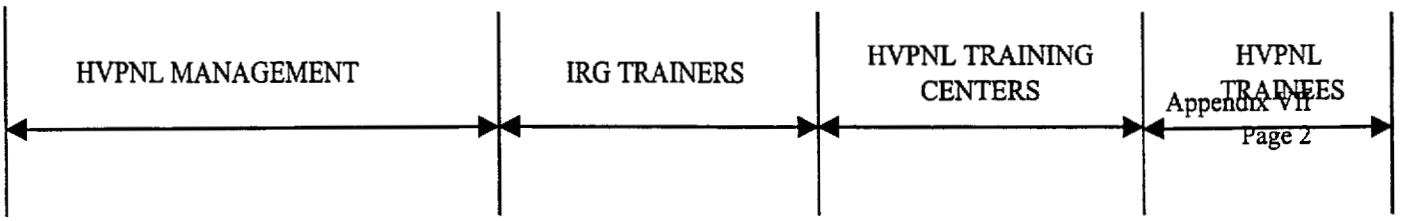
INDIA

SEPTEMBER 1998 – DECEMBER 1998

SYSTEM IMPROVEMENT TRAINING PROJECT

IRG/ HVPNL INTERFACING





SYSTEM EFFICIENCY FIVE-DAY SEMINAR

- DAY 1 LECTURES

  MORNING – INTRODUCTION
  AFTERNOON – SWITCHYARDS

- DAY 2 LECTURE

  MORNING – SWITCHYARDS

  TUTORIAL

  AFTERNOON – TUTORIAL

- DAY 3 LECTURE & HANDS-ON COMPUTER
  ALL DAY – INTRODUCTION TO COMPUTERS

  WALK-DOWN THERMO-VISION SCAN
  EVENING – SCANNING OF SWITCHYARD & DISTRIBUTION SUBSTATIONS

- DAY 4 WALK-DOWN, HANDS-ON TRAINING
  ALL DAY – WALK-DOWN OF SUBSTATION AND PREPARATION OF "ACTION ITEMS" LIST

- DAY 5 HANDS-ON COMPUTER ANALYSIS
  ALL DAY – COMPUTER ANALYSIS OF DISTRIBUTION LINES
  END – AWARD OF CERTIFICATES

TRAINING SCHEDULE
&
TRAINING GROUPS

Schedule	Training Center	Training Group	Switchyard	Switchyard Engineer Engineer
9/24/98 – 10/27/98	Panchkula	1A	Pinjore	Balraj Sheoran
10/28/98 – 11/1 /98	Panchkula	1B	Babyal	B R Garg
11/2/98 – 11/6/98	Panchkula	1C	Pehowa	T C Gupta
11/9/98 – 11/13/98	Karnal	2A	Karnal	K L Jawa
11/16/98 – 11/20/98	Karnal	2B	Nilocheri	C D Pasrkha
11/23/98 – 11/27/98	Karnal	2C	Madhuban	I Leekma
11/30/98 – 12/4/98	Hisar	3A	Hisar 220 kV	Mr Ramdhan
12/7/98 – 12/11/98	Hisar	3B	Beer	Mr Ramdhan
12/14/98 – 12/18/98	Hisar	3C	Beer *	Mr Ramdhan

* Hansi was fogged in

GROUP 1A

HVPNL System Efficiency Improvement Training
Class Begining September 24 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 24 Sep	Day 2 25 Sep	Eve 2 25 Sep	Day 3 28-Sep	Day 4 26-Oct	Day 5 27 Oct
Balraj Sheoran	64659	A E	Ambala	Panchkula	Pinjore Substation	X	X	X	X	X	X
Devinder Singh Rathee	563792	A E	Ambala	Panchkula	Panchkula Substation	X	X	X	X	X	X
Amandeep Singh	01733 53465	A E	Ambala	Panchkula	Madanpur Substation	X	X	X	X	X	X
Kuldeep Singh		A E E (T/L) Construction	Panchkula	Ambala	Panchkula Substation	X	X	X	X	X	X
Deepak Sharma	566117	A.E M&P	Ambala	Panchkula	N/A	X	X	X	X	X	X
Vijay Gupta		A.E E	Yumuna Nagar	Yumuna Nagar	Yumuna Nagar S/D No 1	X	X	X	X	X	X
Mohan Lal Gupta		A E T/L for S S E	Yumuna Nagar	Jagadhari	Gobindpuri Substation	X	X	X	X	X	X
Pramsagar Gupta		A E E M & T	Ambala	Yumuna Nagar	N/A	X	X	X	X	X	X
Rajiu Mishra		A.E	Yumuna Nagar	Naraingarh	Naraingarh S/D	X	X	X	X	X	X
T K Mahajan		A.E E	Yumuna Nagar	Jagadhari	Jagadhari S/D City	X	X	X	X	X	X
K D Dogra	566758	S E Training	Panchkula			X	X	X	X	X	X
S K Gupta	566758	XEN Training	Panchkula	N/A	N/A	X	X	X	X	X	X
A K Vermani	552212	XEN Training	N/A	Ambala	N/A	X	X	X	X	X	X
A K. Mittal		A.E E Training	Panchkula			X	X	X	X	X	X

GROUP 1B

HVPNL System Efficiency Improvement Training
Oct 28 - Nov 1 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 28-Oct	Day 2 29-Oct	Day 3 30-Oct	Eve 3 30-Oct	Day 4 31-Oct	Day 5 1-Nov
S L Bindal	550-593	AEE	Ambala	Ambala City	West Ambala City	X	✓	✓		✓	✓
B K Goyal	50349	AEE	Ambala	Yamuna Nagar	M & P Yamuna Nagar	X	✓	✓		✓	✓
A P Mehta	550232	S D O	Const PKL	Ambala	Construction Ambala City	X	X	✓		✓	✓
R K Sharma	566117	A E E	Ambala	Panchkula	M&P PKL	X	✓	✓		✓	✓
P.K. Malhotra	32650	A E E	Yamunin Nagar	Yamunain Nagar	M/Town Yamuna Nagar	X	X	✓		✓	✓
A P Jain	20992	A E E	Const T C C IV Panchkula	Kurukshetra	Const S/Div No 1 KKT	X	✓	✓		✓	✓
R.L Chand	22471	S D O	Ambala	Ambala Cantt	S/Div No 1 Ambala Cantt	X	✓	✓		✓	✓
B S Kamboj	520540	S D O	Ambala	Ambala City	Model Town Ambala City	X	✓	✓		✓	✓
Rajesh Gupta	530378	A E E	Ambala	Ambala City	66 kV S/Stn Layalpur Bash Ambala City	X	Transferred				

GROUP 1C

HVPNL System Efficiency Improvement Training
Nov 2 - Nov 6, 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 2-Nov	Day 2 3-Nov	Day 3 4-Nov	Eve 3 4-Nov	Day 4 5-Nov	Day 5 6-Nov
Ram Kumar	21850	A E E	Kurukshetra	Kurukshetra	OP S10 No II Kurukshetra	Present	Present		N/A		
R L Goel	26900	A E E	Ambala	Kurukshetra	AEE / M&P Kurukshetra	Present	Present		N/A		
H C Gulati	85250	A E	KKR	Shahabad	Shahabad	Present	Present	Present	N/A	Present	Present
S K Arya	21680	A E E	Const Panchkula	Const Kurukshetra	Const S/D No II Kurukshetra	Present	Present		N/A		
A K Khanna	87242	A E	Kurukshetra	Pundri	SSE T/L Sub Division Pundri	Present	Present	Present	N/A	Present	Present
Manoj Kumar	22356	A E	KKTRA	Kaithal	SDO op S/D No 1 Kaithal	Present	Present		N/A		
V K Chawla	24245	A E E/ S S E	KKTRA	Kaithal	AEE/SSE T/L Sub Div Kaithal	Present	Present		N/A		
Atam Prakash	653343	A E E	Ambala	Panchkula	A E E M&T (lab)	Present	Present		N/A		

HVPNL System Efficiency Improvement Training
Nov 9 - Nov 13 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 9-Nov	Day 2 10-Nov	Day 3 11-Nov	Eve 3 11-Nov	Day 4 12-Nov	Day 5 13-Nov
G.C. Arora	(R) 287769 (O) 275940	A E	M & P Circle Delhi	M & P Div Faridabad	M & T Lab Faridabad	Present	Present				
V K Katyal	52041	A E E	Op Circle SNP	Op Division Gohana	132 kV S/Stn Gohana	Present	Present				
K L Jawa	252196 258923	A E E	Op Circle Karnal	XEN (Works) Op Circle Karnal	S S E 132 kV S/Stn Karnal	Present	Present				
P P Mittal	238043 238372	A E	Op Circle Faridabad	Op Division Ballabgarh	S/U Ballabgarh	Present	Present				
Sik Bhardwaj		AEE	Op(C) Karnal	Op Division Panipat	S/U Panipat	X	X				
Mangal Singh Sorot		A.E.	M&P Delhi	M&P Div. Gurgaon	M T Lab Gurgaon	X	X	X			
R.K Garg		AEE	CONST GURGAON	CONST GURGAON	CONST GURGAON	X	X	X	X		

GROUP 2B

HVPNL System Efficiency Improvement Training
Nov 16 Nov 20 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 16 Nov	Day 2 17 Nov	Day 3 18 Nov	Eve 3 18 Nov	Day 4 19 Nov	Day 5 20 Nov
D S Rathee	361253 361240	A E E	Op Gurgaon	(Works) Op Gurgaon	SSE 220 kV Badshahpur	Present	Present	18/11			
R K Garg		A E E	Const Gurgaon	Const Gurgaon	Const Gurgaon	Present	Present				
S K Bhardwaj		A E E	Op Karnal	Op (City) Panipat	S/V S/D Panipat	Present	Present	Previous Week	Previous Week	Previous Week	Previous Week
V B Chaudhary	362355 362366	A E E	Op Gurgaon	Op S/division Sohna	Op S/div Sohna	Present	Present				20/11
K R Kamboj		A E E	Const Panchkula	Const Kurukshetra	Const Pehowa	Present	Present				
A K Garg	46240 46362	A E E	Op Karnal	Sub-Urban No I Karnal	Op S/D Nilokheri	Present	Present			Previous Week	Previous Week
A K Raheja	42047	A E E	Op Karnal	Sub-Urban No I Karnal	OP S/D Taradri TARAORI	Present	Present	18/11	18/11	19/11	20/11
Naresh Sardana	53663	A E E	M & P Delhi	M & P Panipat		Present	Present	18/11	18/11	19/11	20/11
S N Sharma	80115	A E E	Op Circle Sonipat	S/U Divn Sonipat	S/U Sub Divn Ganaur	Present	Present	18/11	18/11	19/11	20/11
D S Chauhan	234533	A E E	OP Circle Faridabad	T & S MTC Divn Faridabad	T & S Mtc S/Divn Faridabad	Present	Present				
R K Sehgal	275541 234811	A E E	OP Circle Faridabad	Op OLd Faridabad	Mathura Road S/Div Faridabad	Present	Present	18/11			20/11
Inder Jeet	51759 51760	A E	Op Circle Narnaul	Op Div Rewari	Op S/D City No II Rewari	Present	Present				
Mangal Singh Sorot	340021	A E	M & P Delhi	M & P Gurgaon	M & T Lab Gurgaon	Present	Present		Previous Week	Previous Week	Previous Week
R P S Chauhan		A E E	TOC KRL	gard Constr KRL	Const No 2 Panipat	Next Week	Present				
Gulshan Nagpal	261288	A E E	Const	Const FBD	T/L Const BLB	Next Week	Present				20/11

GROUP 2C

HVPNL System Efficiency Improvement Training
Nov 23 - Nov 27 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 23-Nov	Day 2 24-Nov	Day 3 25-Nov	Eve 3 25-Nov	Day 4 26-Nov	Day 5 27-Nov
Navin Kumar Verma	01282-51291	S D O	Narnaul	Narnaul	City Subdiv	Present	Present				
Mohd Zaki	01732-24789	S D O	Panchkula	Ambala City	Yamuna Nagar	Present	Present				
S K Sachdeva	0129 215683	Addl XEN	Faridabad	Faridabad	Faridabad	Present	Present				
Jai Dayal Singh Bamel	0124-322339	A E	Gurgaon	City Gurgaon	City 2 Gurgaon	Present	Present				27/11
Mahavir Singh Dahiya	01264-41099	Addl XEN	Sonepat	City Sonepat	Industrial Area	Present	Present				
Amar Jeet Singh	71057	S S E	Karnal	S/U Div No I Karnal	220 kV S/S Nissing	Present	Present				
Shamsher Singh Sandhu	254101 P P	Add Xen	M & P Delhi	M & P Panipat	M & T Lab Karnal	Present	Present				

GROUP 3A

HVPNL System Efficiency Improvement Training
Nov 30 - Dec 4, 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 30-Nov	Day 2 1-Dec	Day 3 2-Dec	Eve 3 2-Dec	Day 4 3-Dec	Day 5 4-Dec
Jaipal Singh	30468	A E E	'OP' Hissar	'OP' Tohana	OP' Tohana	Present	1/12	2/12	2/12	3/12	4/12
R S Kundu	44136	A E	M & P Hissar	M & P Bhiwani		Present	1/12	2/12	2/12	2/12	4/12
Sajjan Kumar Garg	31863	A E E	TCC I Hissar	T/L (C) Narwana	Gnd (C) Narwana	Present		2/12	2/12	3/12	4/12
O P Arora	43491	A E	Operation Circle Bhiwani	(Op) City Bhiwani	Const S/D I Bhiwani	Present	1/12		2/12	3/12	4/12
K K Sarin	42961	A E E	M & P Hissar	M & P Rohtak	M & P Rohtak	Present					
O.P Ahlawat	20049	AEE	'Op' Sirsa	'Op' Sirsa	'Op' Ellenabad	-					

HVPNL System Efficiency Improvement Training
Dec 7 - Dec 11 1998

GROUP 3B

Dec 18

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 7-Dec	Day 2 8 Dec	Day 3 9-Dec	Eve 3 9 Dec	Day 4 10 Dec	Day 5 ~~11 Dec~~
Shiv Kumar Aggarwal	0-1686 82063	A E E	Op Jind	Op Safidon	Safidon Operation Subdivision	Present					
Rajbir Singh	01262-43479	A E E	Rohtak	City Rohtak	SSE 132 kV Rhotak	Present					
Surinder Kumar Bansal	42106	A E E	Jind	Narwana	Sub-Urban Narwana	Present					
Raj Pal Singh	01664-44136	A E E	M&P Hisar	M&P Bhiwani	M&P Bhiwani	Present					
V P Gupta	0-1681 55641	A E E	Op Jind	Op Jind	Sub Urban S/Div 2 Jind	Present					
V K BHARDWAJ	01662 50046	A E E	HISSAR	OP HANSI	SSE 132kV HANSI	present on 14 12 98					

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GROUP 3C

HVPNL System Efficiency Improvement Training
Dec 14 - Dec 18 1998

Name	Phone	Title	Circle	Division	Subdivision/ Substation	Day 1 14 Dec	Day 2 15-Dec	Day 3 16-Dec	Eve 3 16 Dec	Day 4 17-Dec	Day 5 18 Dec
R K Singla	55627 (O) 55628(R)	A E E	Operation Circle Jind	Operation Division Jind	Operation Subdivision HVPNL Jind	Present					
V K Bhardwaj	50046	A E E	Hissar	Operation Division Hansi	S S E 132 kV S S Hansi	Present	Attended in the previous batch				
J K Bansal	20695 (O) 28699 (R)	A E E	Hisar	T/L Const Div Hisar	A E E / Grid Const S/D Sirsa	Present					
Karan Singh Sehrawat	48961 (O) at RTK	A E	M & P Hisar	M & P Rohtak	M & P DN RTK	Present					
Kamaljit Singh	41337 (R) 40274 (O)	A E	Op' Jind	'Op' Narwana	T/L S/Div Narwana	Present					
M L Aggarwal	82303 (O) 82302 (R)	A E	'Op' Jind	'Op Safidon	S/U S/Div Safidon	Present					
K B Singh	20437 (O) 20695 (O)	A E	Sirsa	Op' City Sirsa	220 kV S/S Sirsa	Present					
D L Hansu	21569 (R) 20325 (O)	A E	Sirsa	Sirsa	SDO G/A Sirsa	Present					
Ajmer Singh	20385	A E E	Hisar M & P	Hisar M & P	M & P Div Hisar	Present					

APPENDIX - VIII

RELEVANT NEWSPAPER CUTTINGS – NOV 1998

(During Training Program)

IRG INTERNATIONAL RESOURCES GROUP

INDIA

NOVEMBER 1998

270

Reduced T&D losses to save 9000 mw power: Kumaramanglam

PRESS TRUST OF INDIA
CALCUTTA, NOV 14

UNION Power Minister P R Kumaramangalam today said that at least 9,000 mw power could be saved by reducing transmission and distribution (T and D) losses from the present 21.5 per cent to eight per cent.

Inaugurating a symposium on "Rhetoric and reality of power in India", here, Kumaramangalam said the state electricity boards (SEBs) and the power utilities should strive to improve the plant load factor (PLF) from 67 per cent to 85 per cent, reduce T and D Loss by 15 per cent and infuse the kind of managerial efficiency to usher in a drastic change in the power scenario in the country

Terming the T and D Loss as "theft and dacoity loss", the minister said a strong social campaign ought to be launched to resist such an offence.

It was amazing, he said, that middle-class consumers were found indulging in such corrupt practices of cheating the Government. The minister equated the offence in power hooking to income-tax evasion and said "we should be honest with each other if a solution has to be found to the problem"

Hailing reforms in some of the state electricity boards, he said that during the first six months in power, the Government had been able to increase PLF by six per cent.

"About 8,000 mw additional power has been realised" he said, adding that national PLF average had shot up to 66.5 per cent from 23 per cent a few years ago

Kumaramangalam said India had bright prospects for churning out 1.80 lakh mw exploitable hydel potential in the next 10 years.

As a long-term solution to power crisis, hydel power was the "best and cheapest option and it has proven potential," he said.

Power generated from the Bhakra Beas hydel project in Punjab cost the state electricity board three paise per unit and is sold to consumers at six paise per unit.

Turning to the subsidy to the consumers, the Power Minister reiterated the Centre's stand on reduced subsidy, but said the state governments were welcome to continue providing subsidy

November 15, 1998, "The India Express", Chandigarh

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Damaged transformers lying abandoned

NAVNEET SHARMA
CHANDIGARH NOV 14

Nov 15/98

THE HVP-BJP government may have restructured the Haryana State Electricity Board (HSEB) into separate generation and distribution companies for higher efficiency but the workforce does not seem to have learnt any lessons. Nearly 8,000 damaged transformers are lying abandoned on roads and parks all over the state, paralysing repair works.

Data available with *The Indian Express* reveals that the problem of damaged transformer - which have been replaced but not transported to the company workshops - is prevalent in all the 13 circles, with Kurukshetra, Karnal, Hisar, Narnaul, Yamunanagar and Hisar circles being the main defaulters. In each of these areas, hundreds of damaged transformers are lying on the roads and parks for months.

In fact, the delay has led to a significant increase in cases of theft of transformers in the state - over 300 transformers are reported to have been stolen in the first six months of the current year as against 450 last year In addition there have been many instances of theft of key parts of transformers, according to sources.

The Haryana Vidyut Prasaran Nigam (HVPN) - newly created company for distribution of power - has repeatedly directed the officers incharge of these circles to transport the damaged transformers to workshops for repairs but to no avail Under the norms, these damaged transformers are to be repaired immediately for reinstallation.

Last week, the authorities again directed the superintendent engineers (SEs) of all the 13 circles to comply with directives, warning of strict action in case of failure. While the HVPN management attributes the delay to callousness, the field officers have blamed non-availability of vehicles for their failure to take all the damaged transformers to workshops. "We have been trying hard to get vehicles but there is a severe shortage The higher authorities have already been informed about the problem," said to a senior engineer

November 15, 1998, "The Indian Express", Chandigarh

APPENDIX - IX

EXHIBIT OF A PERSONAL "SWITCHYARD MAINTENANCE SCHEDULE"

(Prepared by an HVPNL – Engineer)

IRg INTERNATIONAL RESOURCES GROUP

INDIA

NOVEMBER 1998

Substation Maintenance Audit

Provided by Mr C D Pasricha A E /S S E , Nilokheri Substation

1 Power & S/Stn Transformers

i) Quarterly
- A) Dielectric Strength of Oil
- B) Check Clean lines of air passage of breather and crystals of silica gel
- C) Check conservator oil level indicator and its float operated mechanism if provided
- D) Check diaphragm of explosion of vents for any breakage
- E) Check temperature indicator for correctness
- F) Water content of oil

ii) Half Yearly
- A) Insulation resistance of winding
- B) Earth resistance neutrals
- C) Bucholz relay operation for alarm and trip
- D) Check operation of Temp Alarm

iii) Yearly
- A) Oil in transformer for acidity
- B) Resistance of transformer windings

iv) After 10 years

- A) Inner inspection including the lifting of core coils

2 Bulk Oil Circuit Breaker (11kV, 33kV, 66kV, 132kV)

i) Monthly
- A) Check oil level of tank

ii) Quarterly

A) Test Oil for dielectric strength thrice a year or after 7 trippings whichever is earlier
B) Check tripping mechanical system
C) Clean and lubricate mechanical system

iii) Yearly

A) Check and clean stationary and bridging contact
B) Check show closing and contact alignment
C) Inspection of contact and clearing grids
D) Insulation resistance
E) Contact resistance checking
F) Oil acidity test

3 Minimum Oil Circuit Breakers 132,66,33,11 kV

i) Monthly

A) Check Oil for dielectric strength thrice a year or after six trippings whichever is earlier
B) Check tripping mechanism
C) Clean and lubricate moving parts
D) Check and clean exhaust pipe
E) Check Oil in the dash pot

ii) Yearly

A) Acidity test of oil
B) Clean and flush quenching chambers
C) Clean and lubricate moving parts
D) Check insulation resistance
E) Inspection of contacts

4 D C System (Batteries)

i) Weekly

A) Recording voltage and specific gravity of pilot cells
B) Check and top up electrolyte level
C) Check making of Trickle/Quick charges

ii) Monthly

A) Inspection of the charge and discharge cycles
B) Checking the temperature specific and voltage of all cells
C) Check tightness of bolted inter cells connections and remove the oxide film

iii) Half-yearly

A) Give equalizing charge to the batteries on float charge
B) Give a conditioning charge with a curative discharge

5 132/66/33 kV Isolators

i) Quarterly
A) Cleaning & Lubrication of main auxiliary contacts
B) Lubrication of bearing joints and oil cups

6 Lightning Arresters

i) Half yearly
A) Checking of earth resistance

7 Substation Earth Resistance

i) Half yearly

8 Capacitors

i) Monthly
A) Ventilation against blocking
B) Check current drawn against rated figures

9 Log Sheet
A) Are the log sheets signed duly by SSE/AO/SDO in charge of the substation
B) Are some log sheets signed by Xen

Improvements for Future

10 General Remarks

i) Provision of T&P Safety Equipment
ii) Replenishment of first aid boxes
iii) Provisions of Trench Covers in control room and yard
iv) Provision of sufficient lighting arrangement in control room

11 Insulation resistance of 11 kV Bus

12 Insulation resistance of 11 kV P T

13 Insulation resistance of 11 kV incoming cables

14 Working of K W 11 meters

15 Condition of fire extinguishers

APPENDIX - X

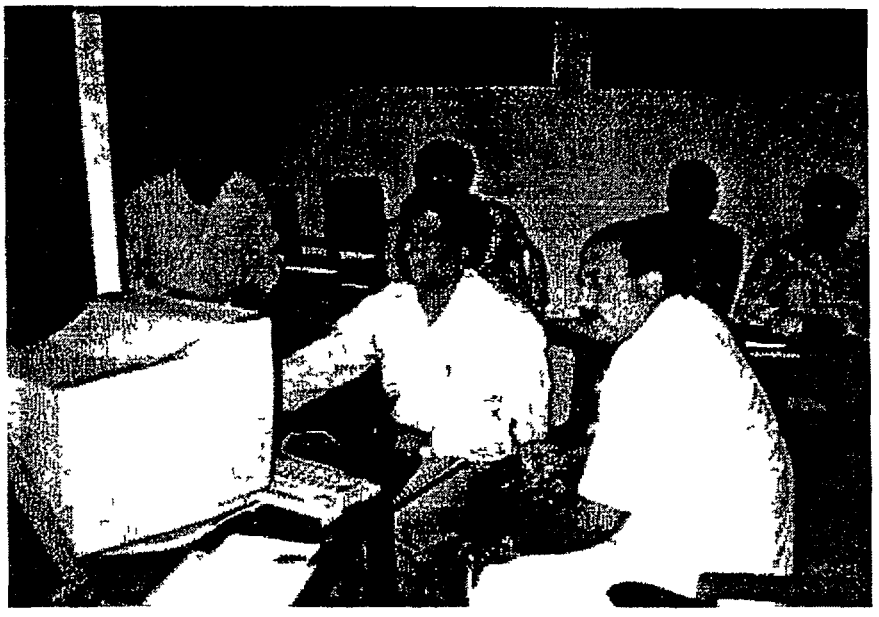
PHOTOGRAPHS

(Taken during Training Walkdowns)

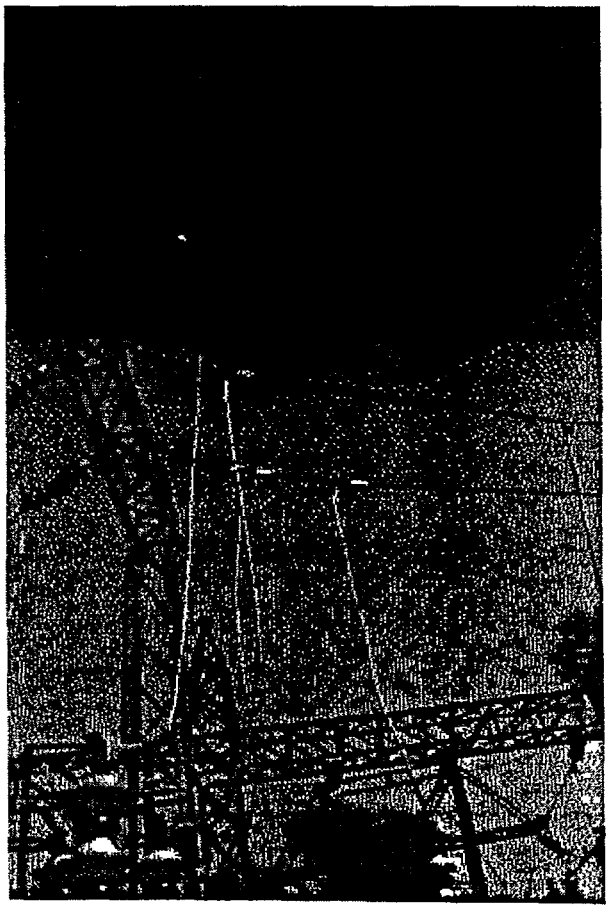
IRg INTERNATIONAL RESOURCES GROUP

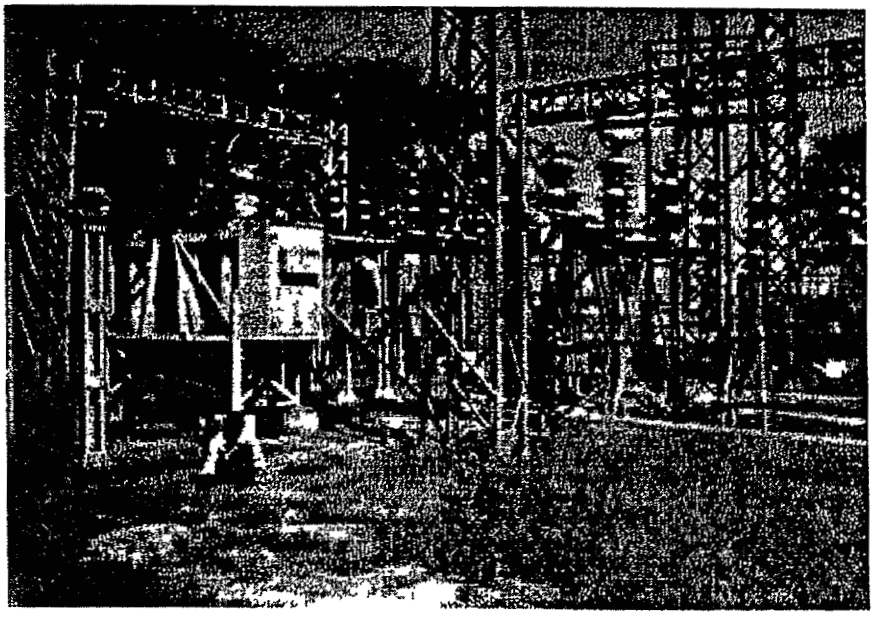
INDIA

SEPTEMBER 1998 – DECEMBER 1998



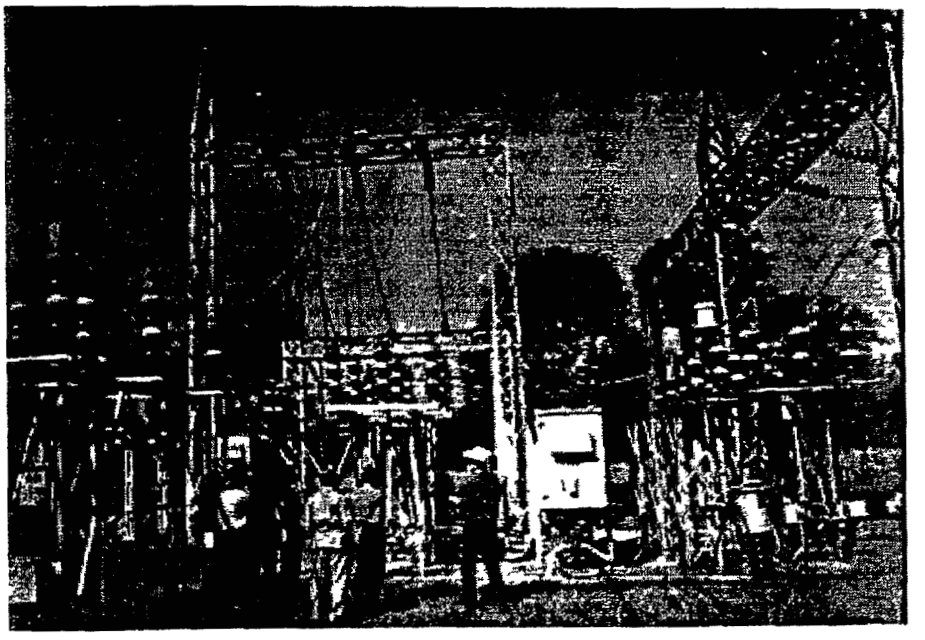
Above participants are receiving 'hands-on instruction for computer design of distribution systems Below these connectors should have been vertical to avoid tight bends in jumpers



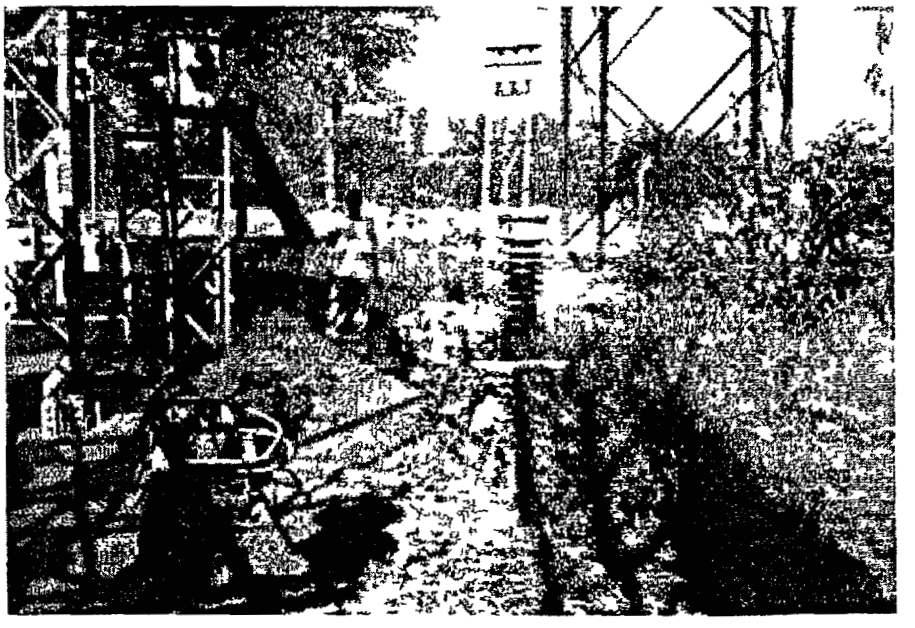


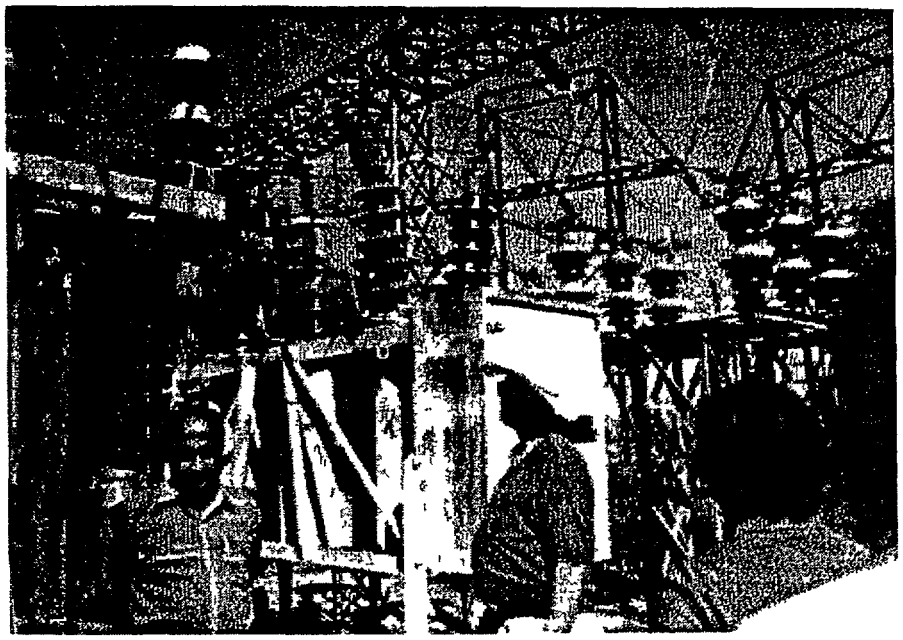
Above there is an absence of a crushed rock surface Below, the cables are incorrectly routed into trench

Appendix X
Page 2

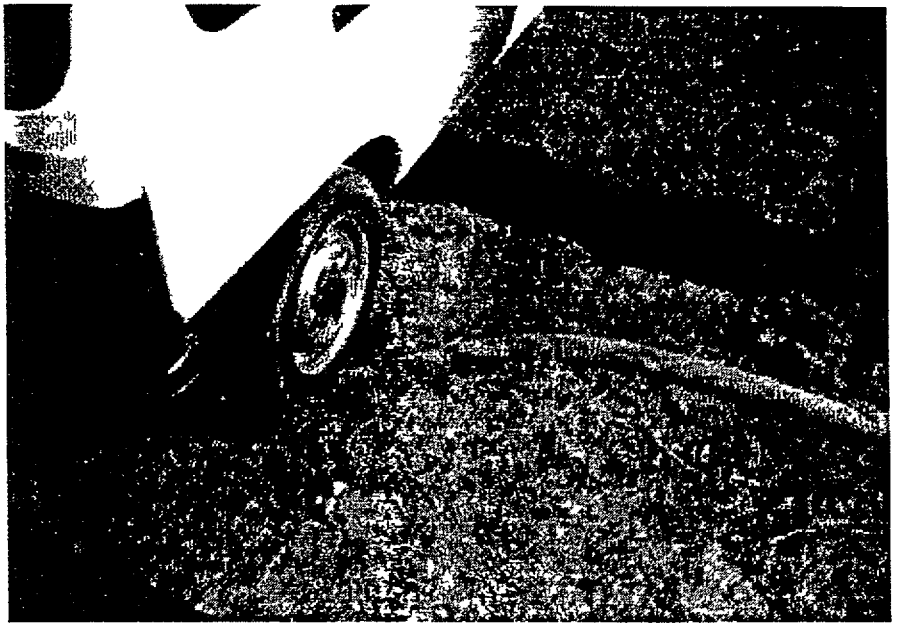


Above the walk-down with the trainees Below are workers clearing the weeds in the switchyard

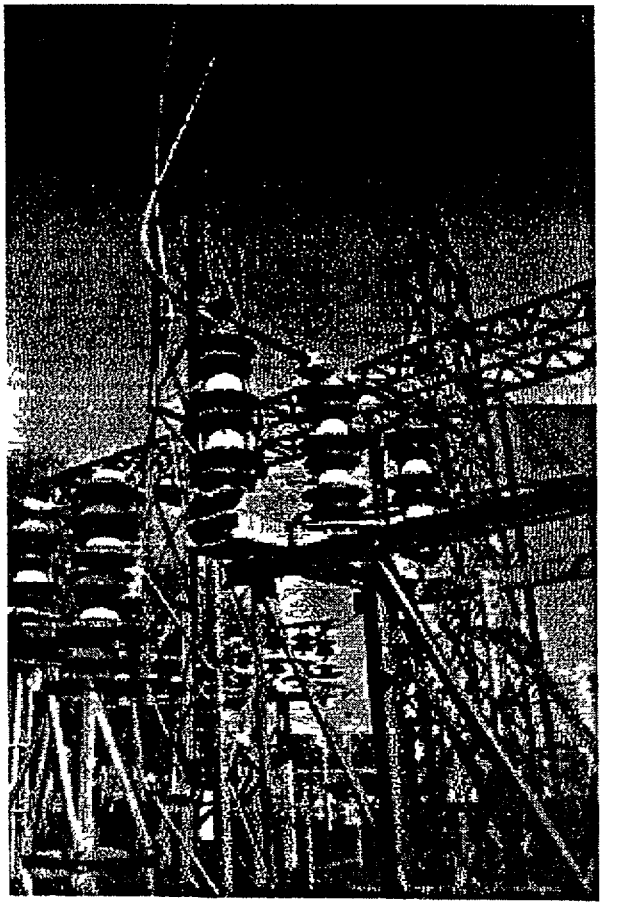


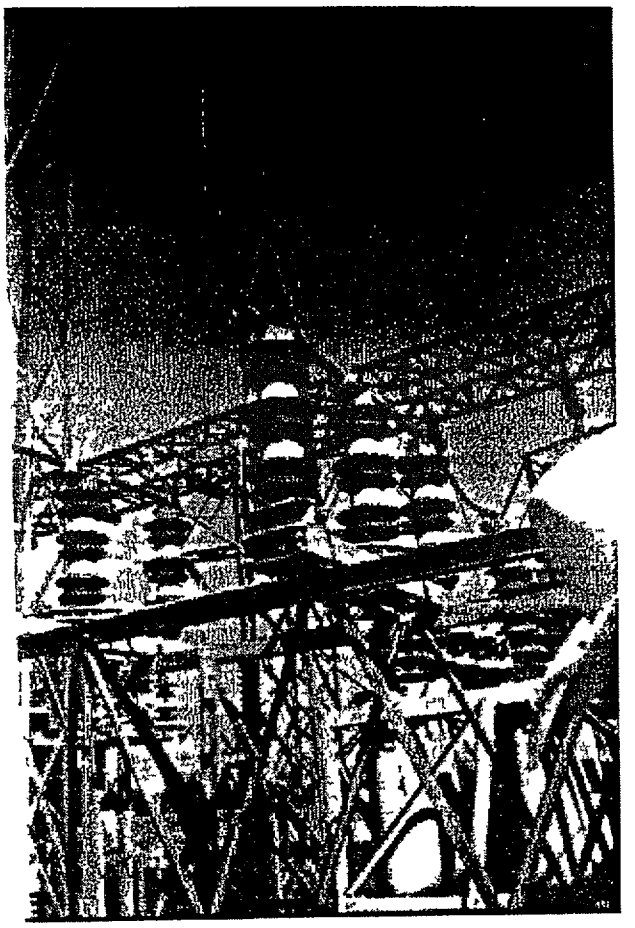


Above is a circuit breaker which is shorted across the RED phase
Below the cable is improperly entering into the trench

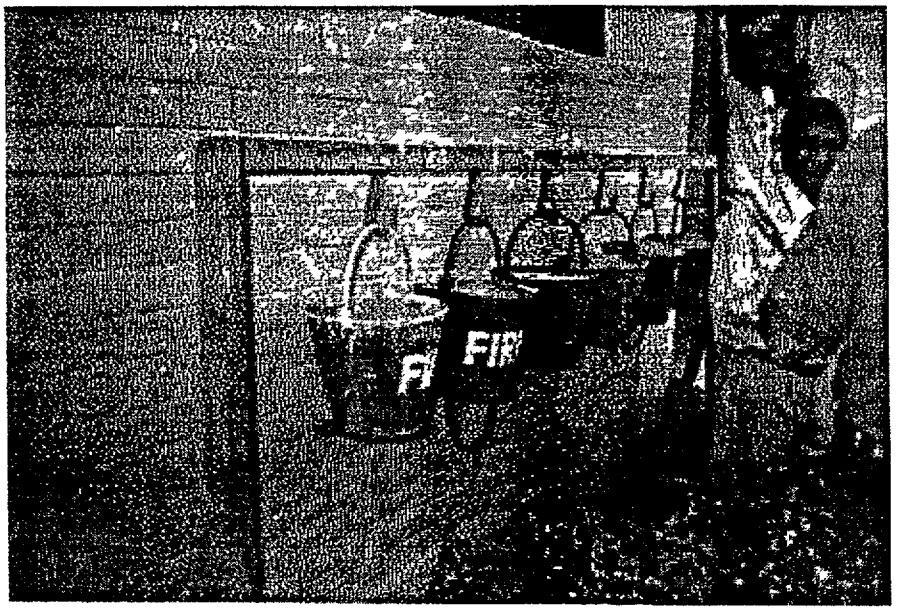


Above the hazards of surface laid cables Below a vertical connector could have reduced this tight bend in the jumper





To the left the strands of the jumper are opening up due to the tight bend On the right two phases on the live 11 kV cable are too close There is no control of spacers Far bottom buckets of sand is the extent of fire protection for the entire switchyard



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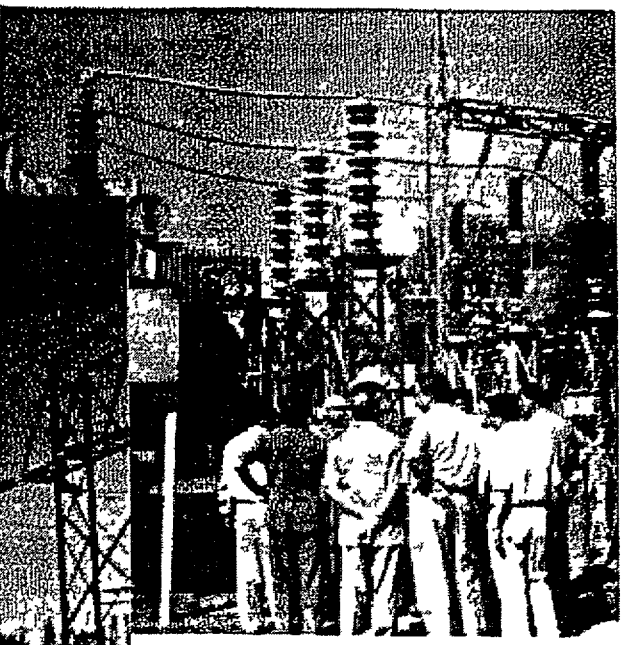
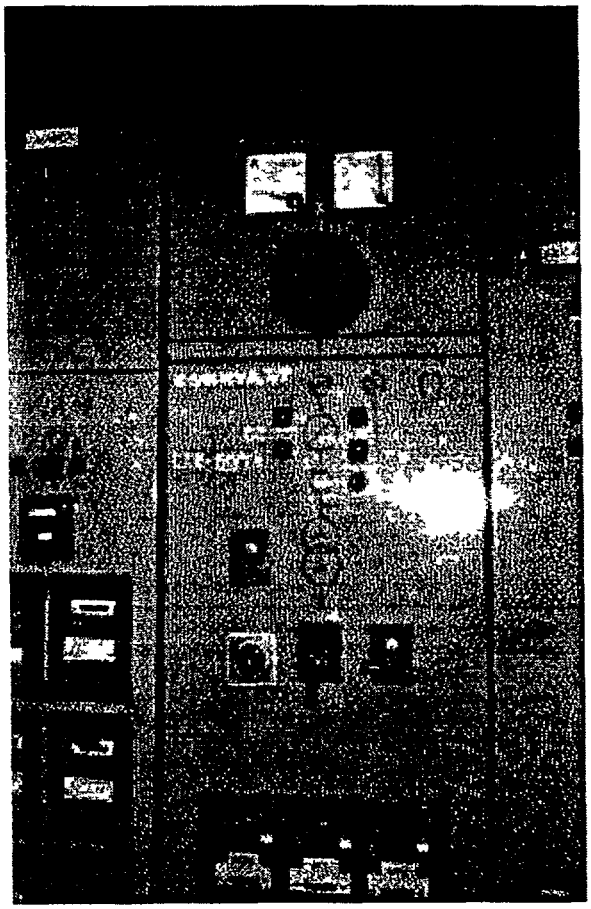
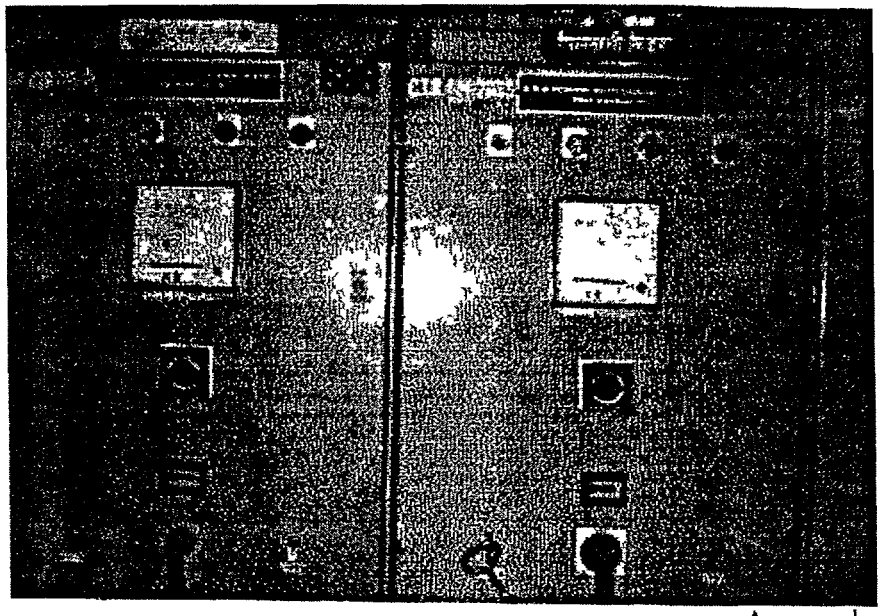
These photos show group instruction during walk-downs

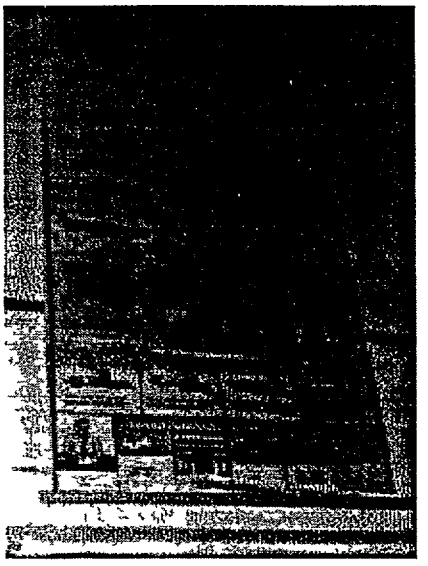




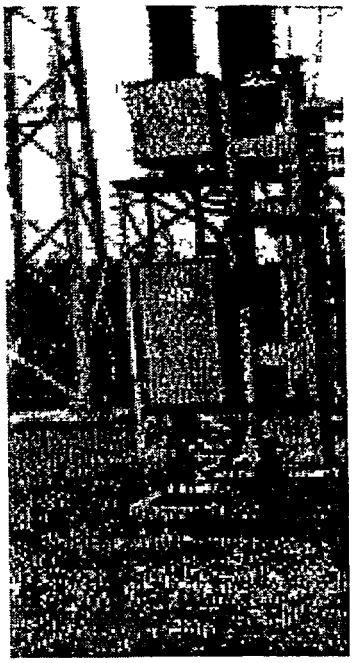
Left All of the bulbs on the indicating lights are burnt out Below neither the indicating lights nor the ammeters are functioning on closed circuits



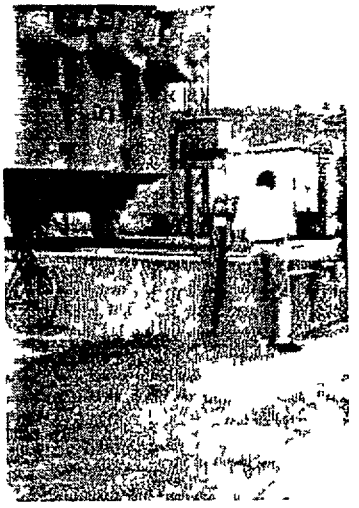
Top Left and Right The PILC cable is leaking oil at the gland at metal-clad switchgear end Bottom Left Good practice of displaying instruction poster for electrocution Bottom Right Group instruction on the computer

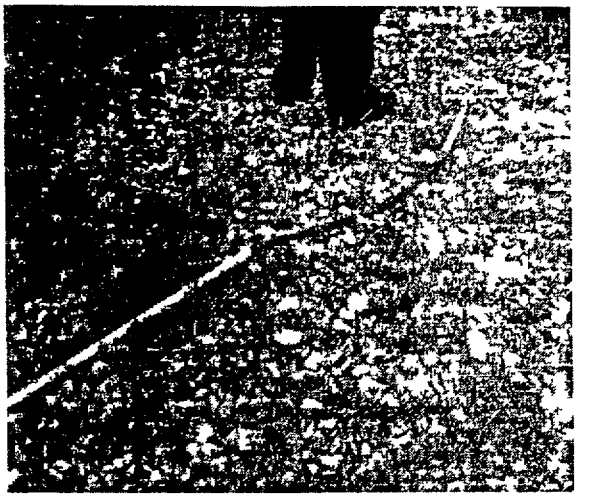


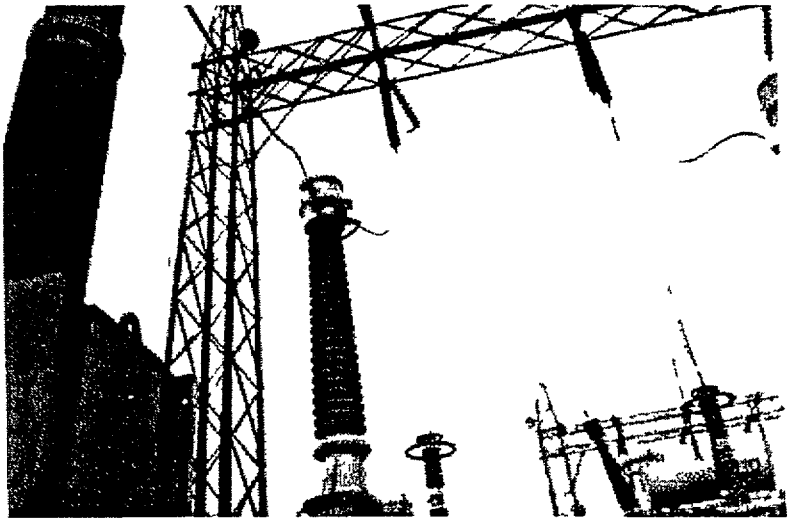
Group computer instruction

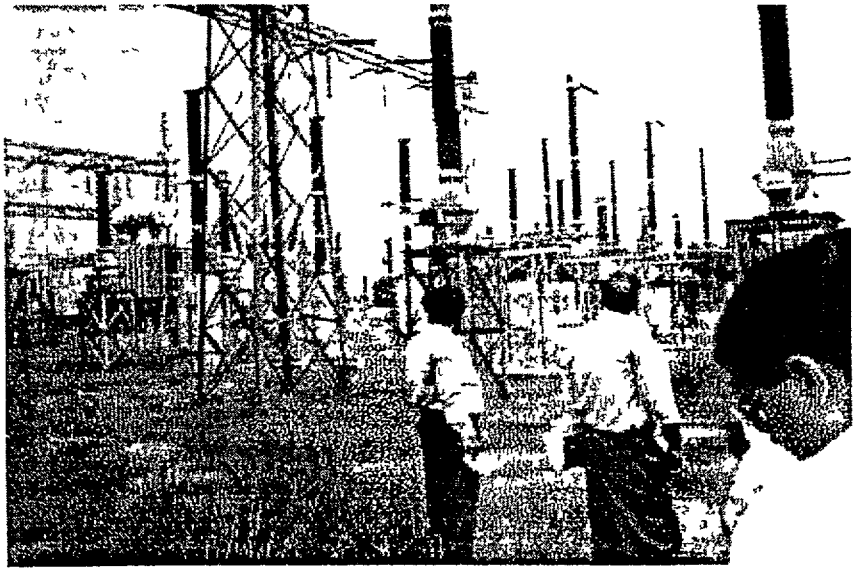


Left The cables should be in conduit and not exposed to the sunlight Middle Trench covers are missing weeds are overgrown and there is no crushed rock surface Bottom A poor control cable installation









Top left A single CO_2 cylinder for fire protection a a large power transformer Top right Electric wires are run along the ground Middle These vertical jumpers are too tight and pulling up on the lightning arresters Bottom The cover of the terminal box was left open

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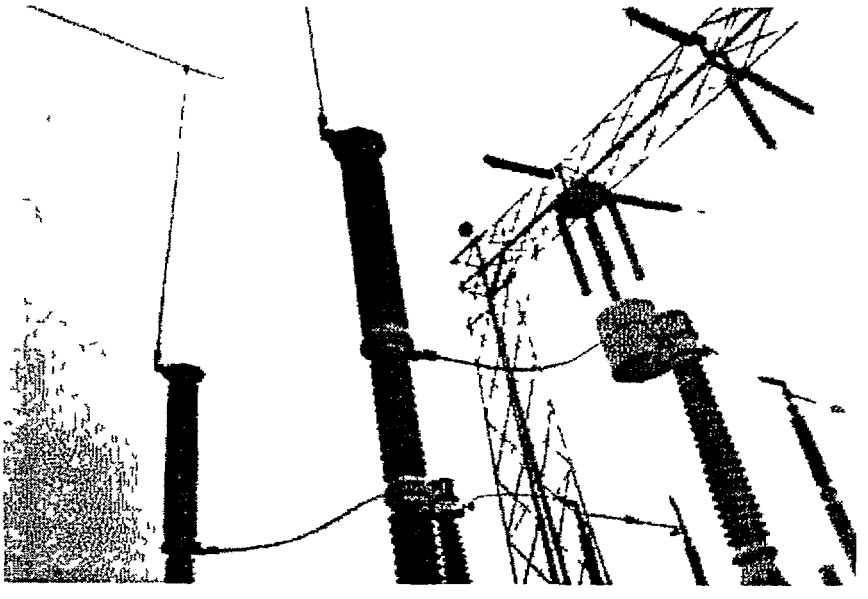
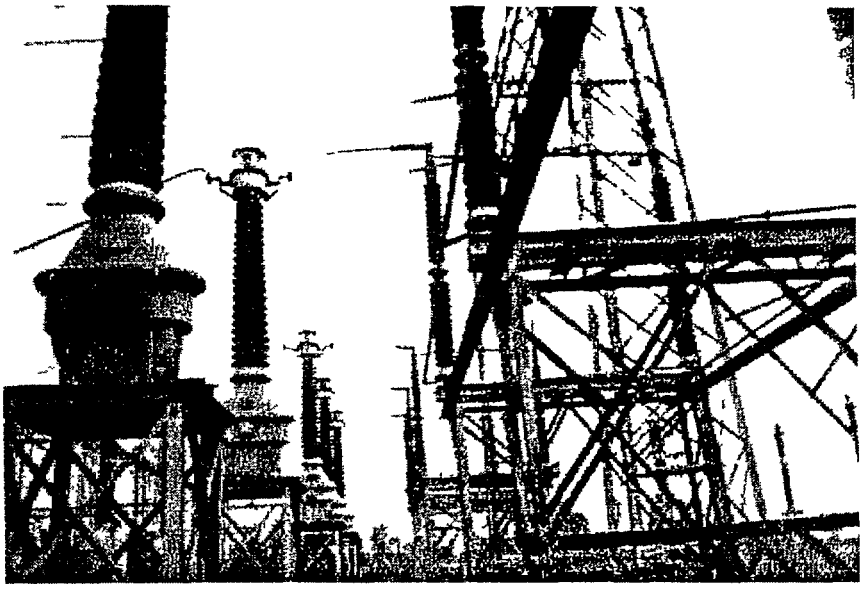
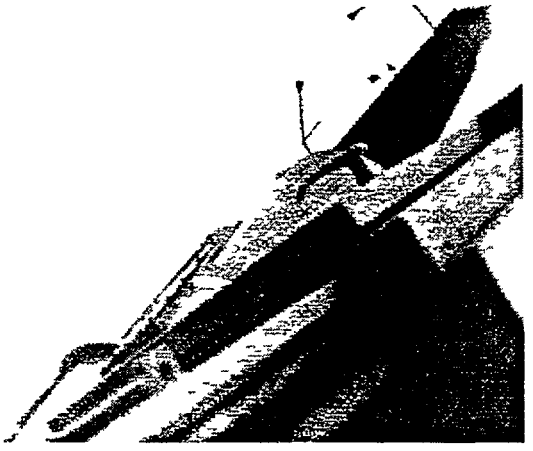
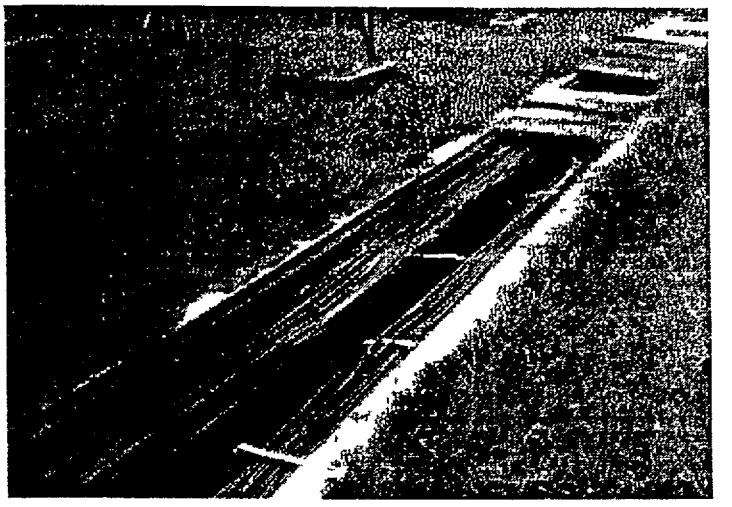
Top Group instruction during walk-down Bottom
A horizontal connector is needed to avoid a tight bend
in the jumper





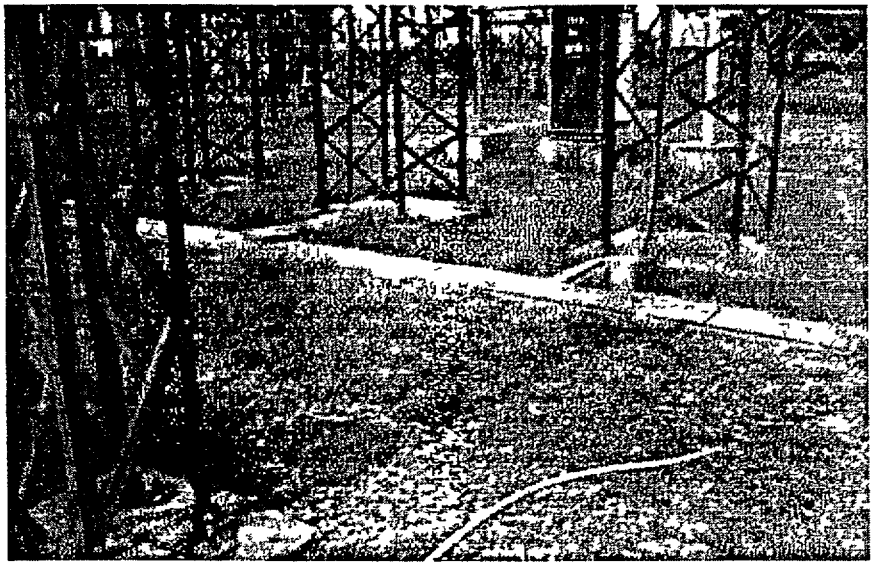
Above Horizontal jumpers are needed to avoid this tight bending radius on the jumper Below sphere gaps are not properly set or aligned

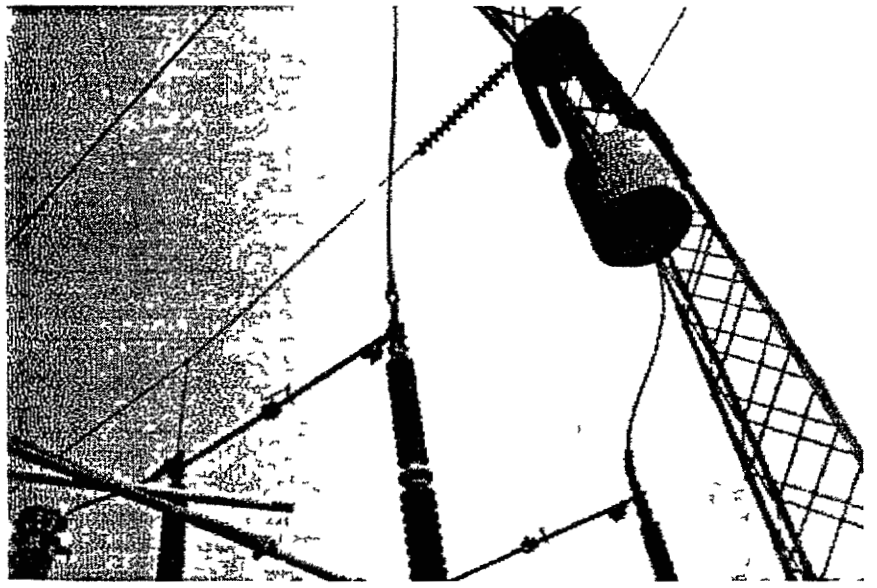




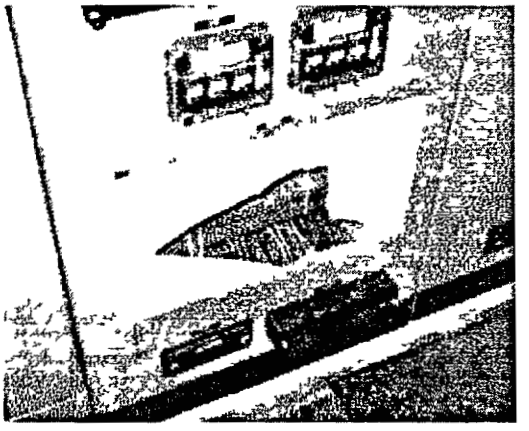
Above The covers of this trench have been left off exposing these cable to sunlight and other elements which can damage

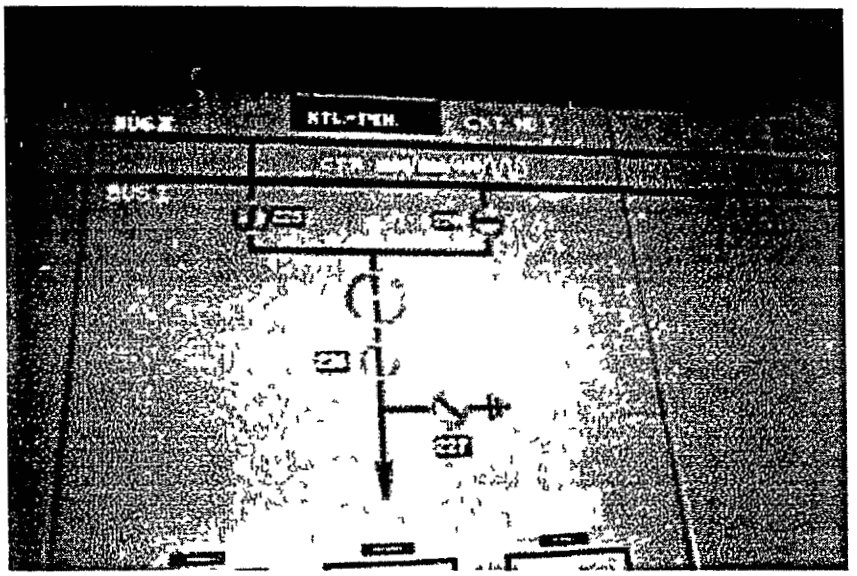
them Below electric wires are run along the ground.



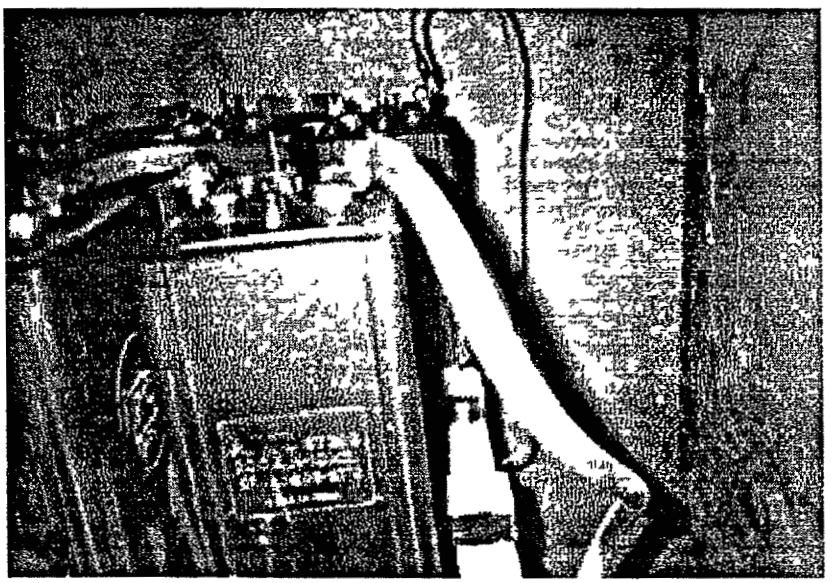


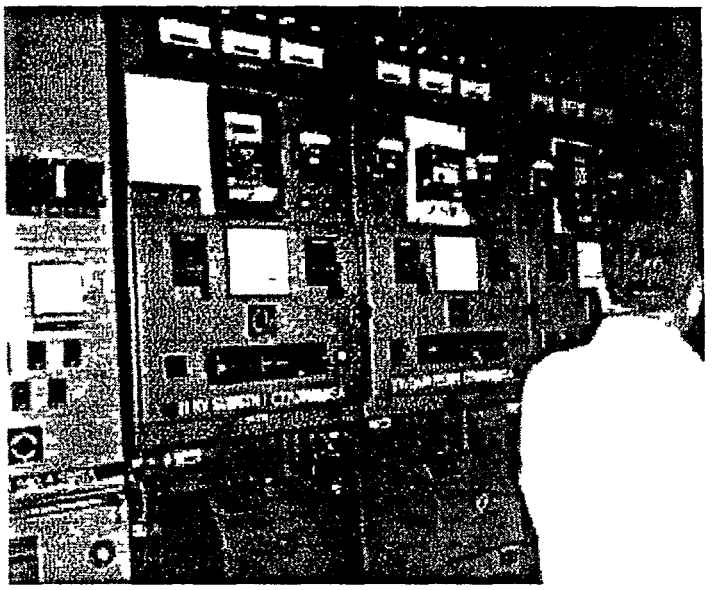
Above these vertical jumpers are too tight Below a missing cover plate was repaced with a piece of paper (now torn)



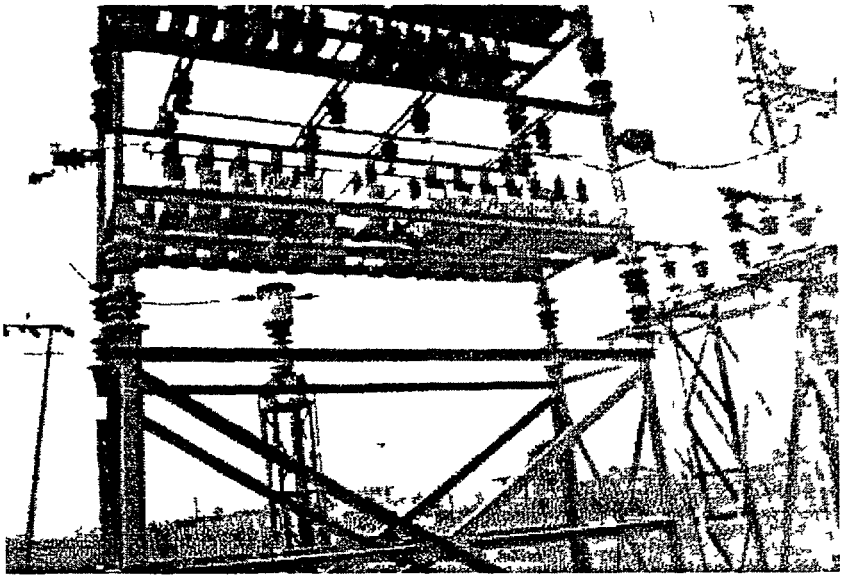


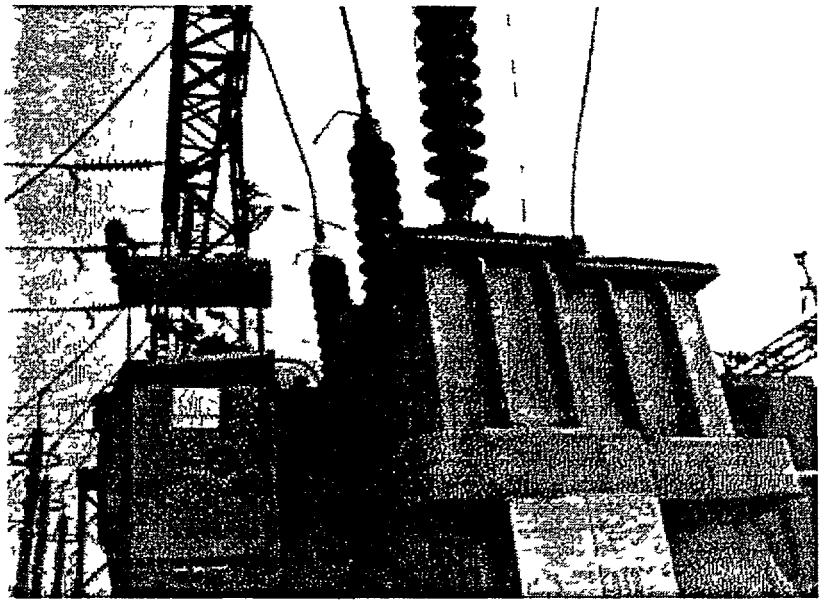
Above semaphores are not functional Below battery cables have no fuses



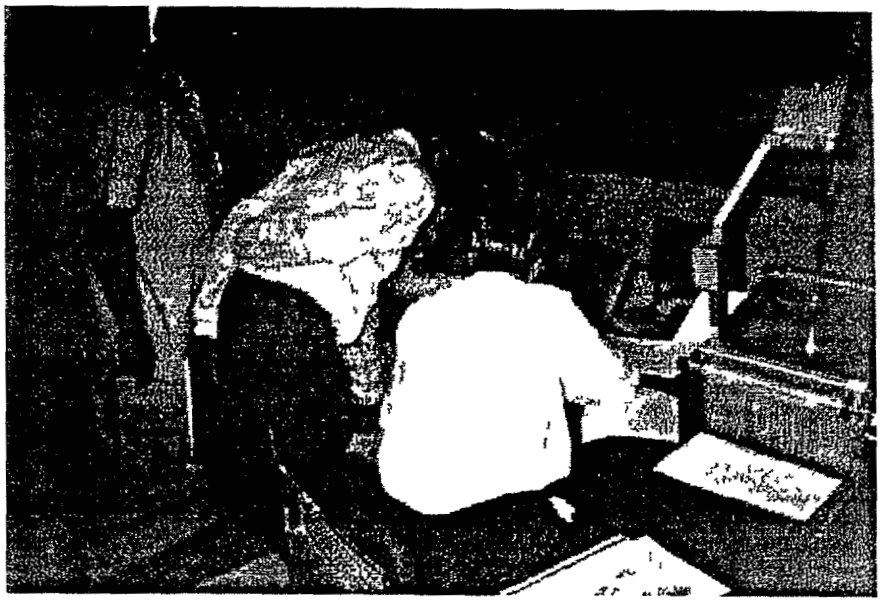


Above many indicating lights are non-functional Below many capacitor units have blown fuses

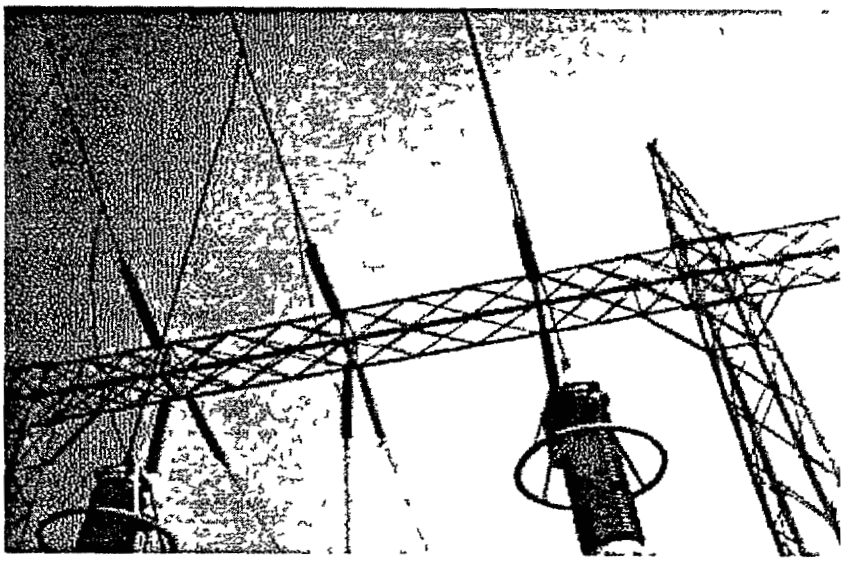


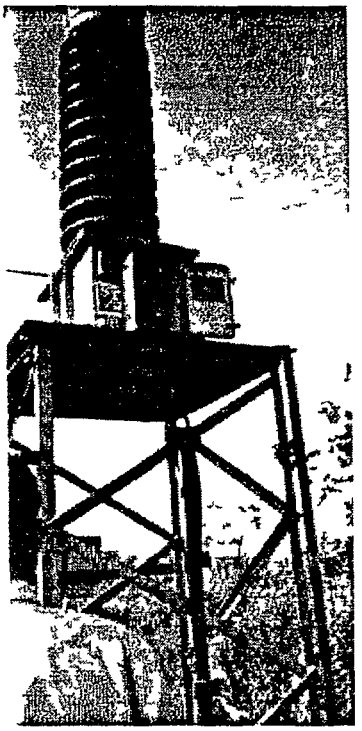


Above arcing horns are missing bottom rods Below covers to trenches are poorly installed

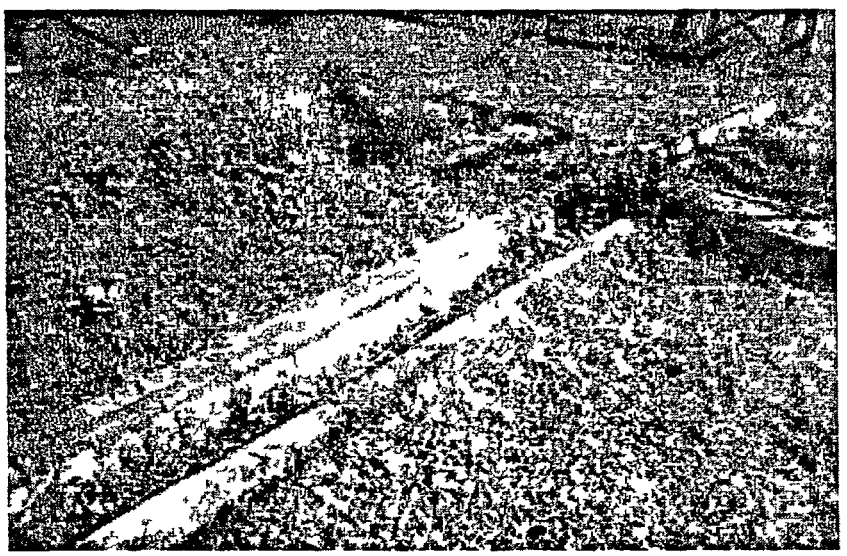


Above classroom computer instruction Below these vertical jumpers are too tight

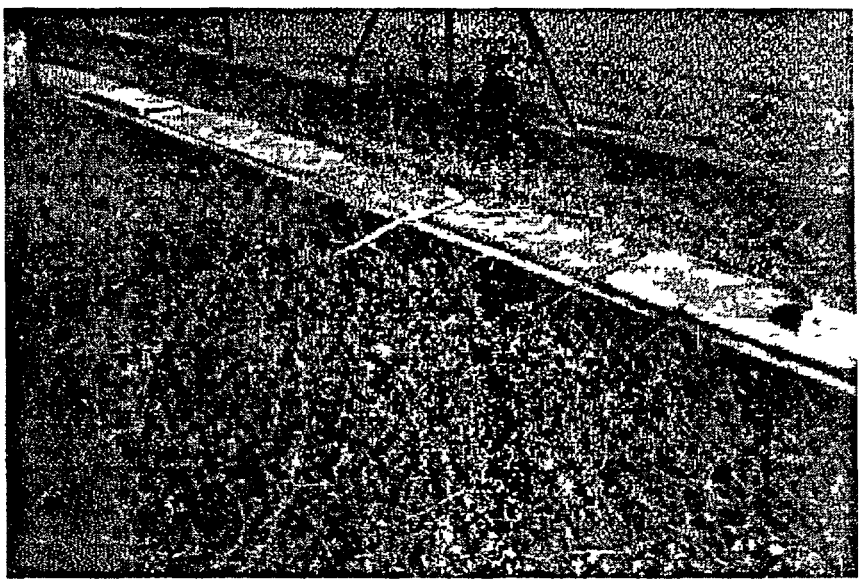


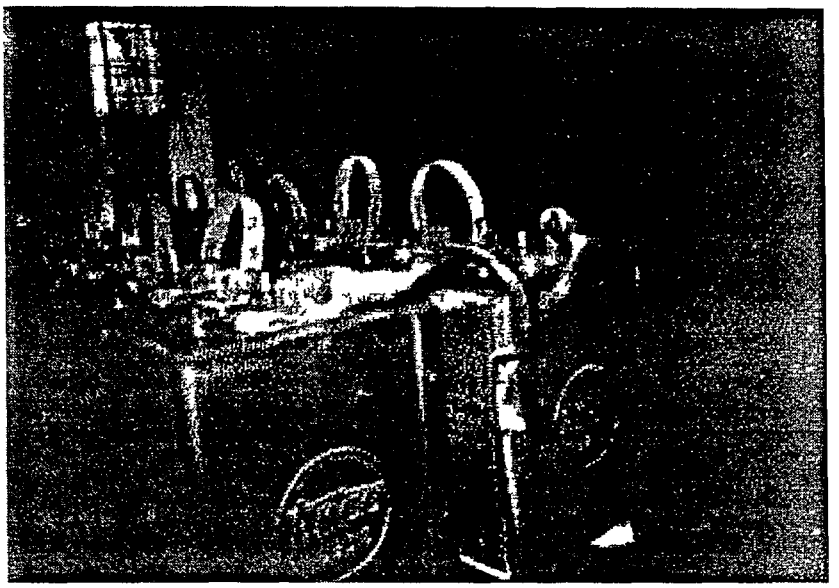


Above control panel covers are left open for extended periods of time Below Cables in trenches are completely exposed

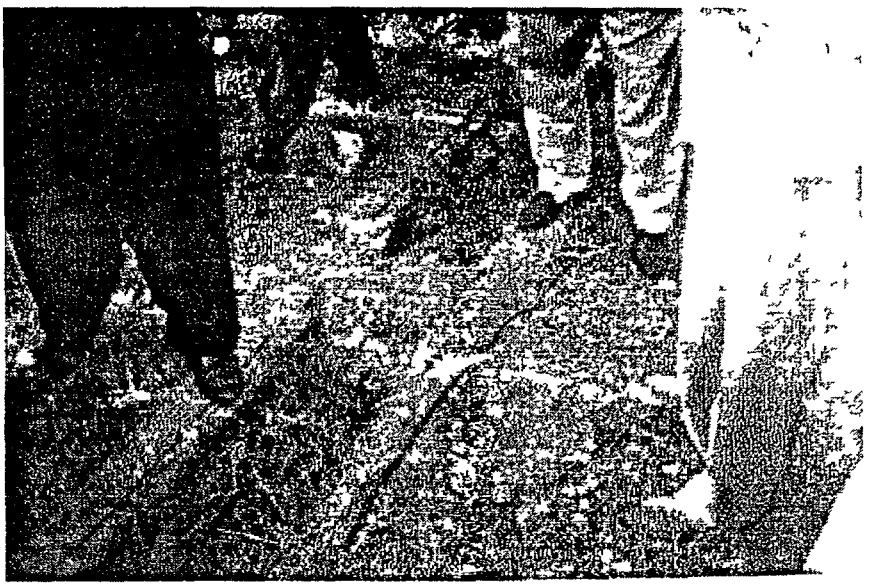


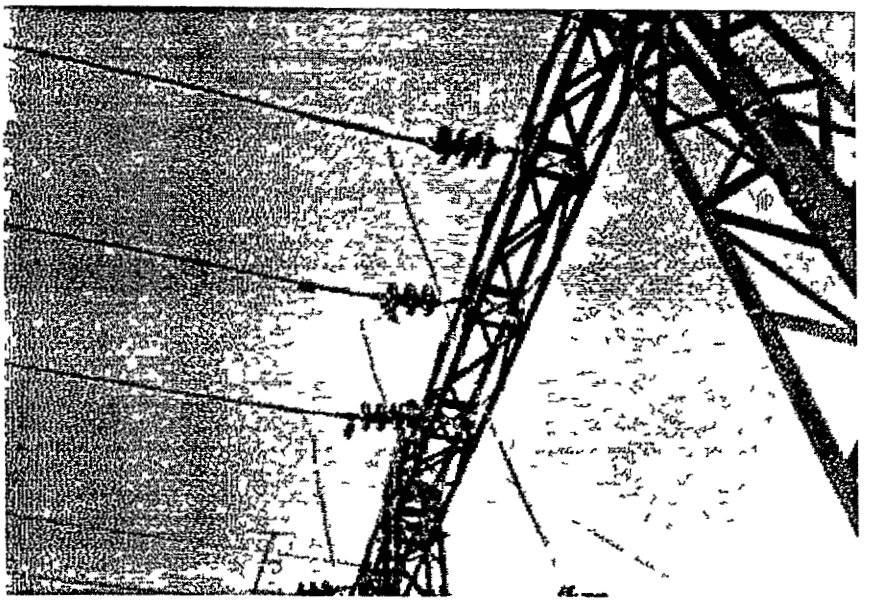
Above these canisters are the extend of fire protection for these large power transformers Below cables are improperly installed entering over lip on trench



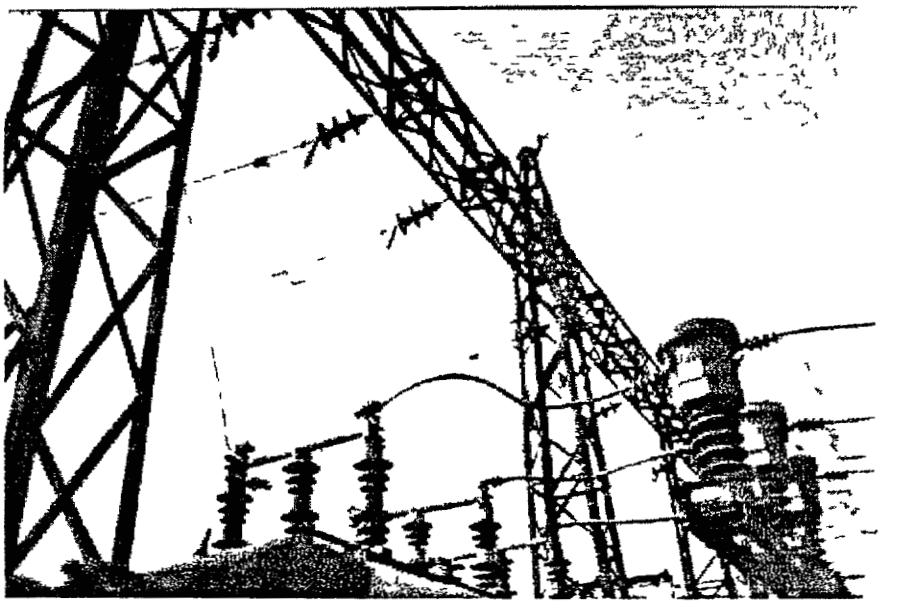


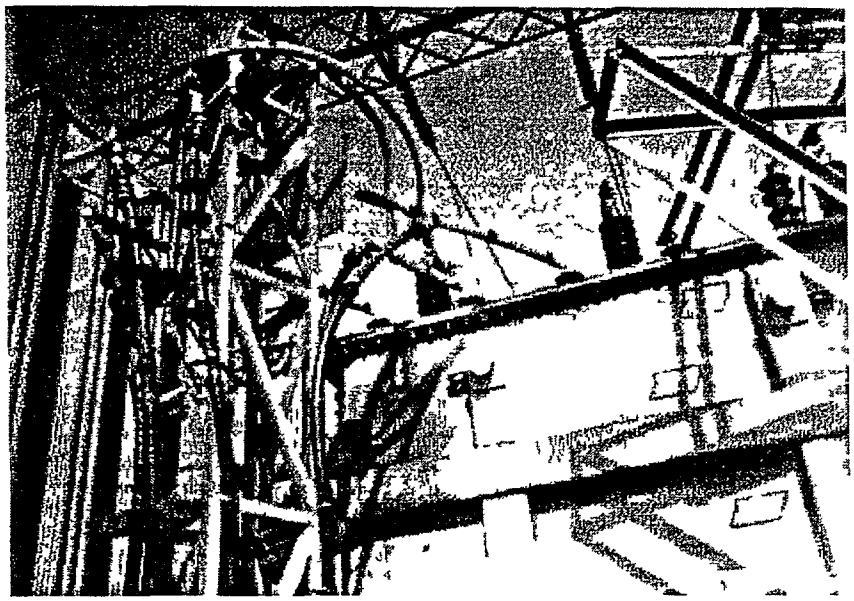
Above battery cables have no fusing Below cables are poorly installed in trenches



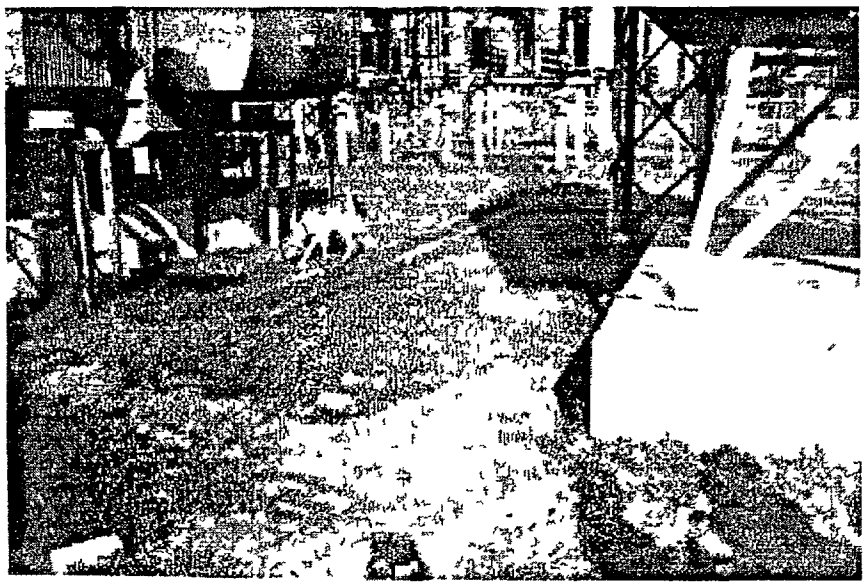


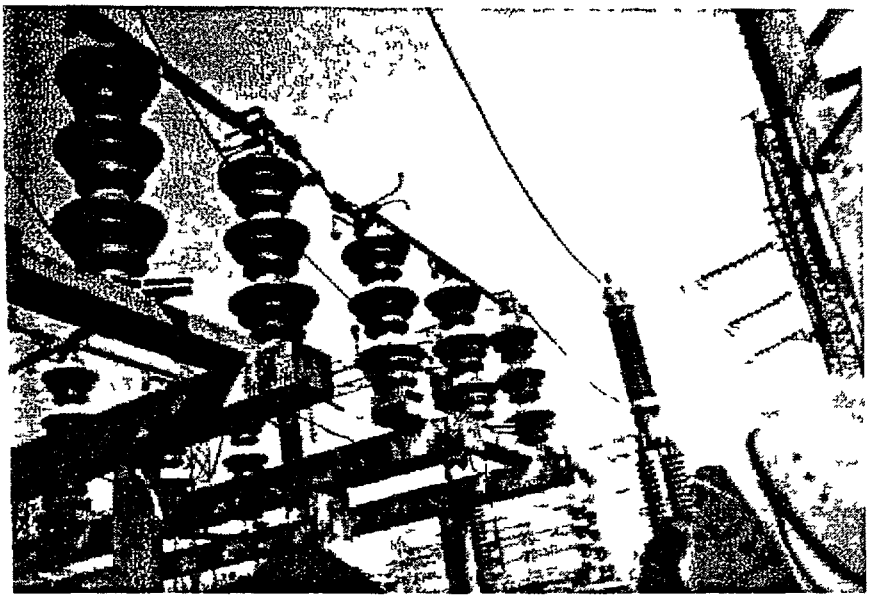
Above three different connectors are used on the three phases This is a poor design Below a wire wrap is used in place of a proper connector





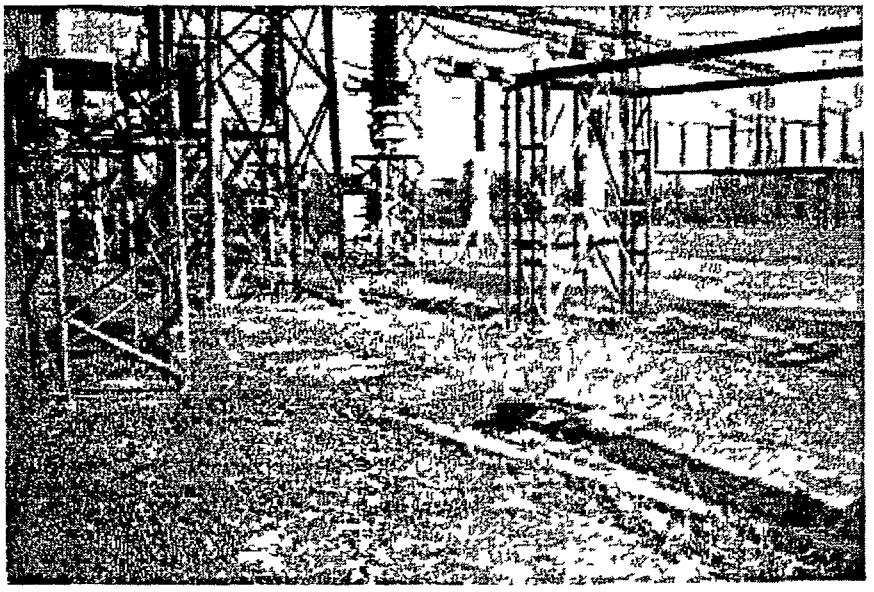
Above clearances on these 11 kV cable terminators are not controlled Below the switchyard surface has no crushed rock and is overgrown with weeds

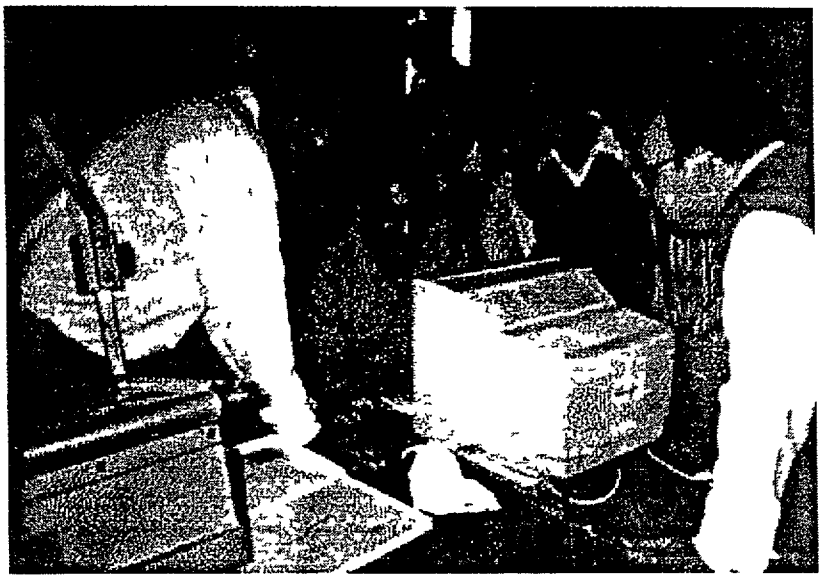




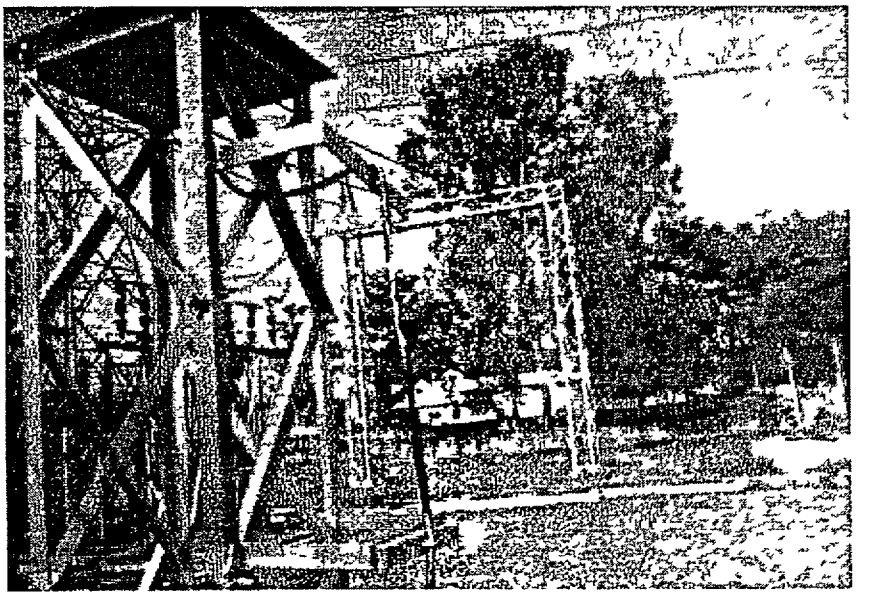
Above sphere gaps are not consistent on each of the

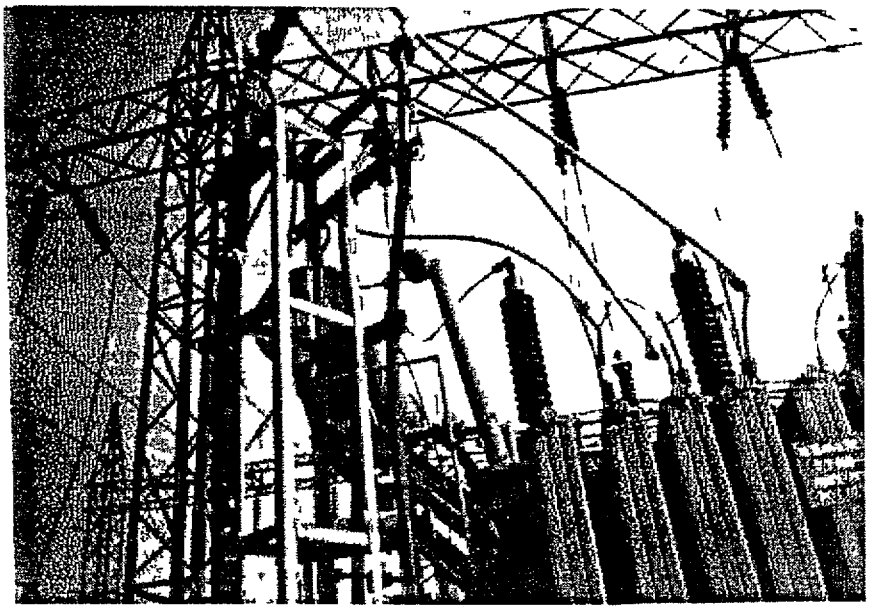
phases Below trenches are poorly maintained.





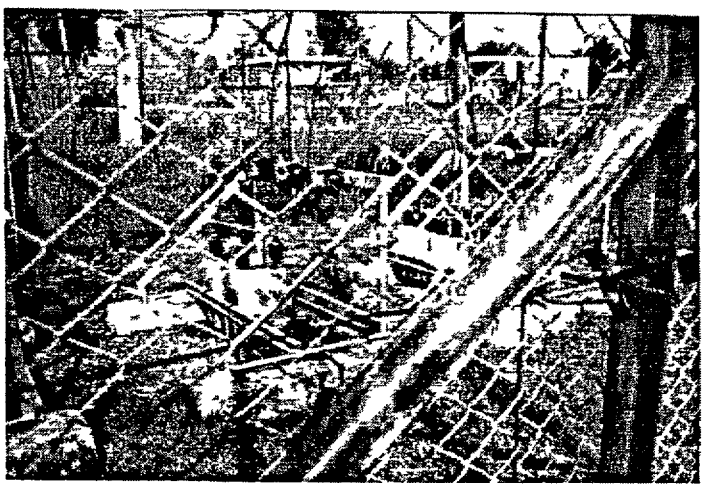
Above group computer instruction Below control cable is poorly installed with a tight bending radius

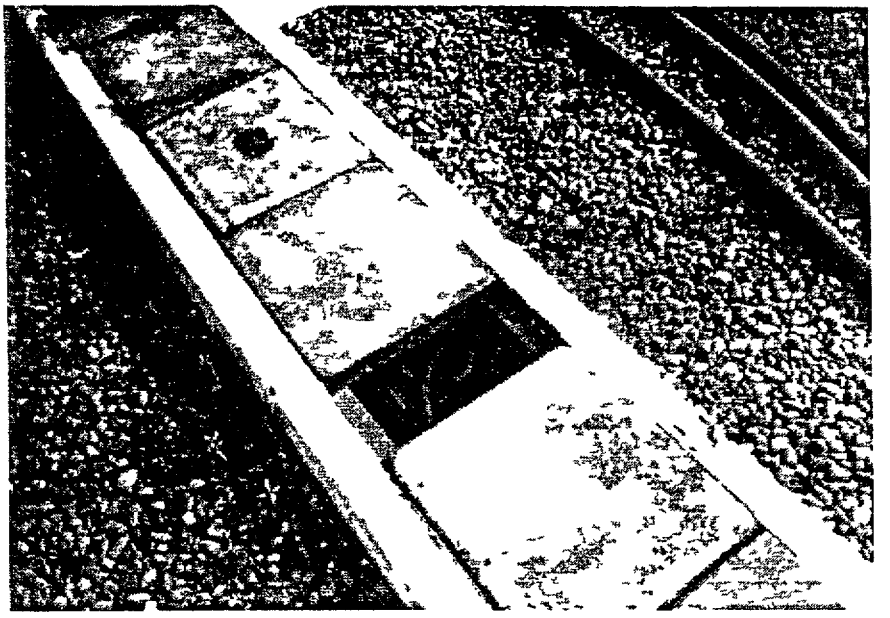




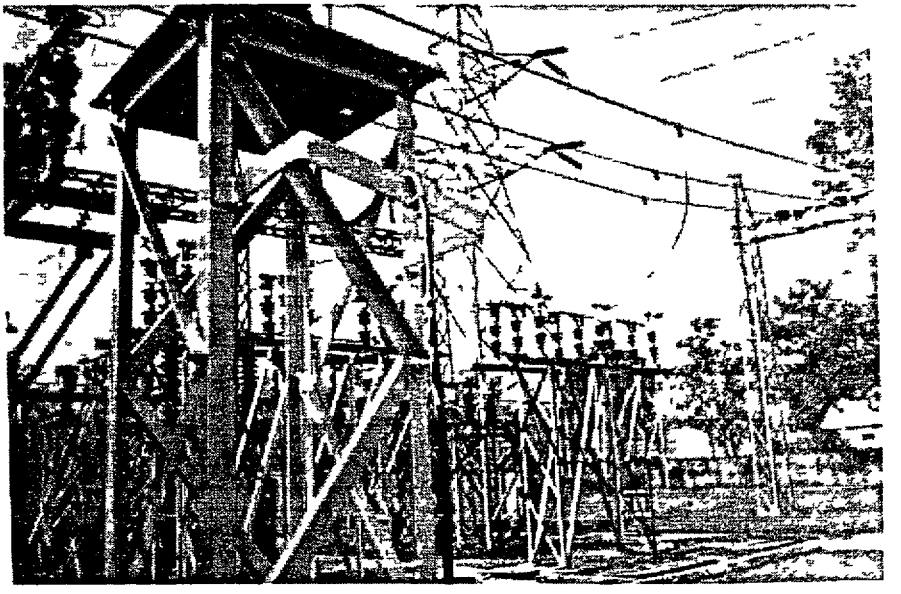
Above and below yellow tape which serves no purpose gives a false sense that the cable is properly insulated

Above and below 11 kV capacitors on the ground is a poor installation practice

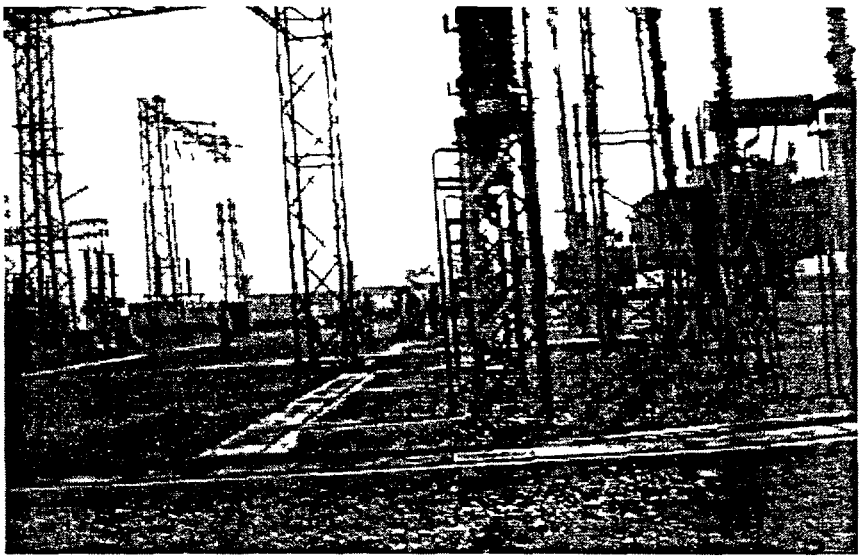


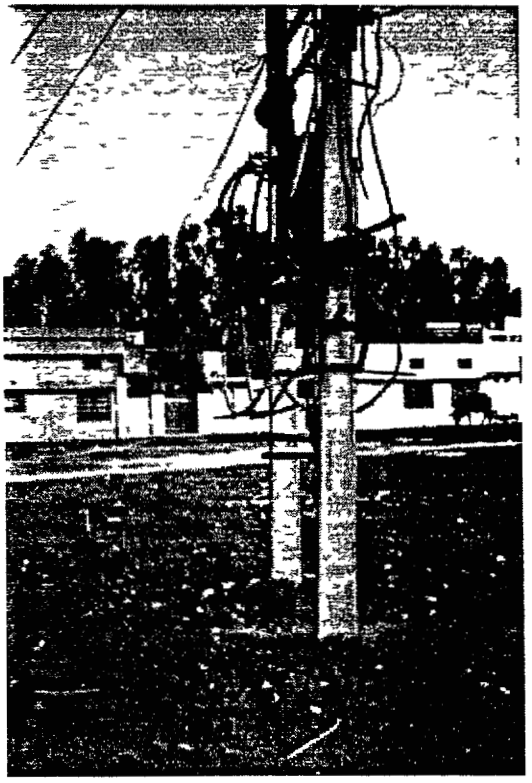


Above and below these control cables have been poorly installed with a tight bending radii

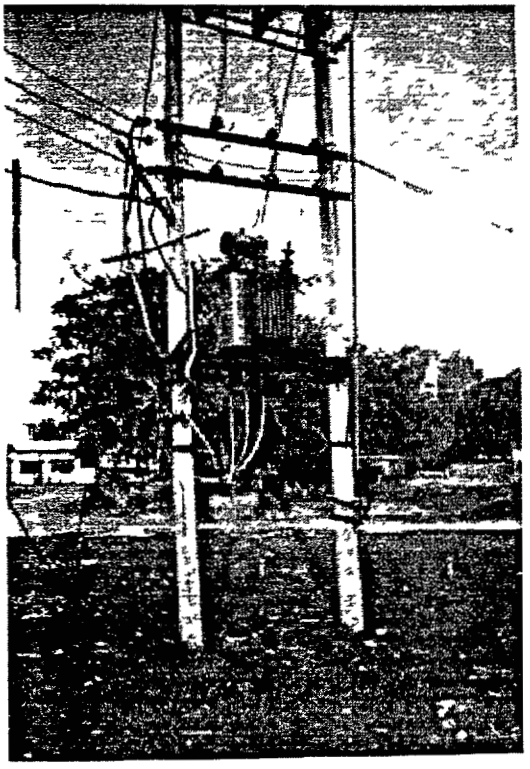


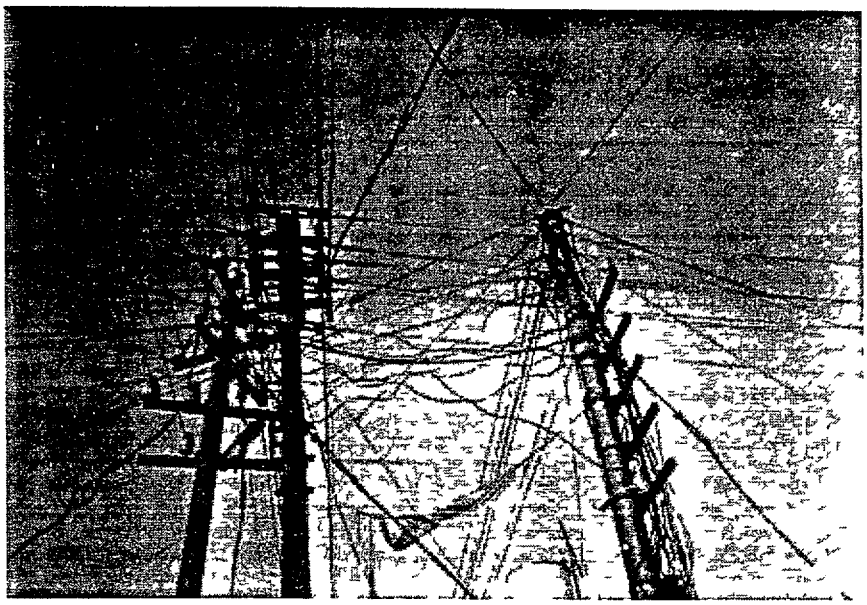
Above and below these 11 kV cable have been installed along the ground instead of being buried properly in a trench or placed in conduit



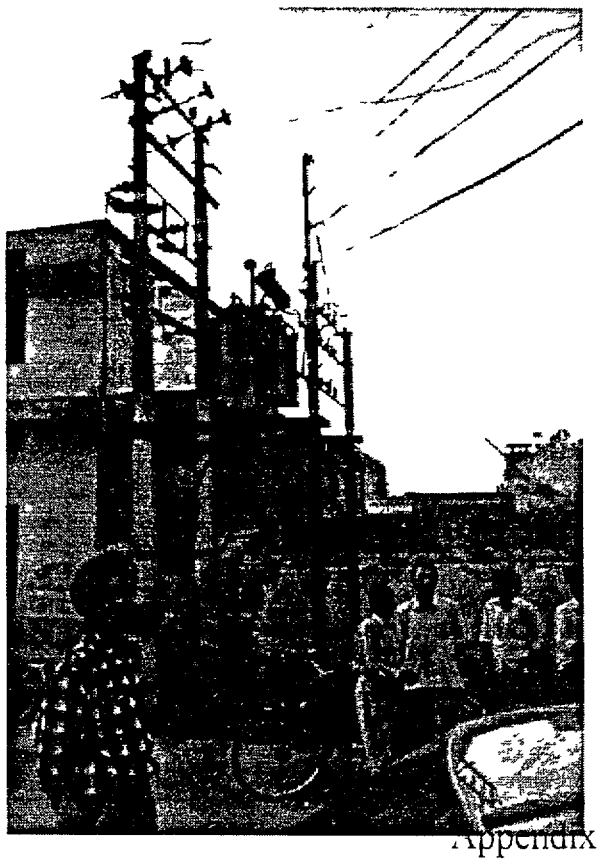


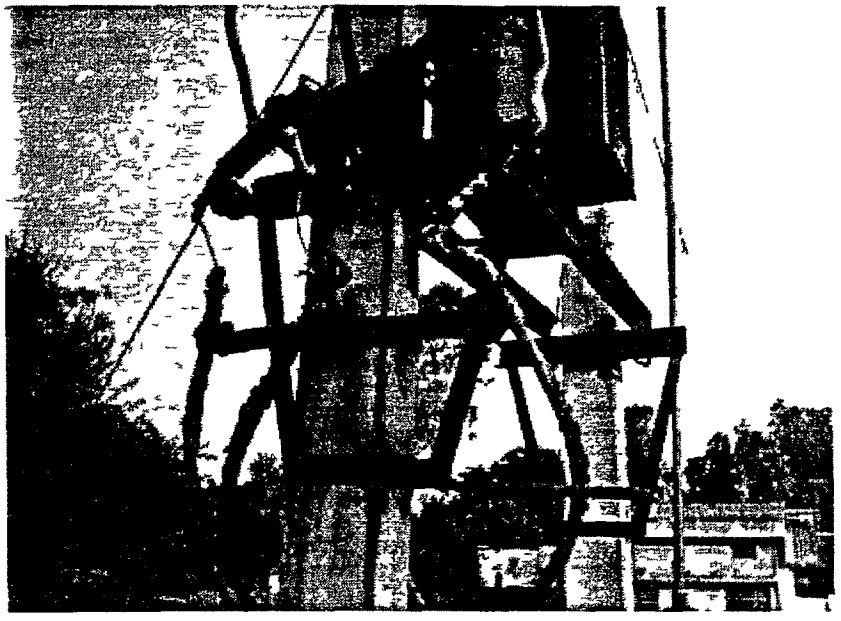
These pictures show a distribution transformer structure where live 415v wires are exposed with no protective cover



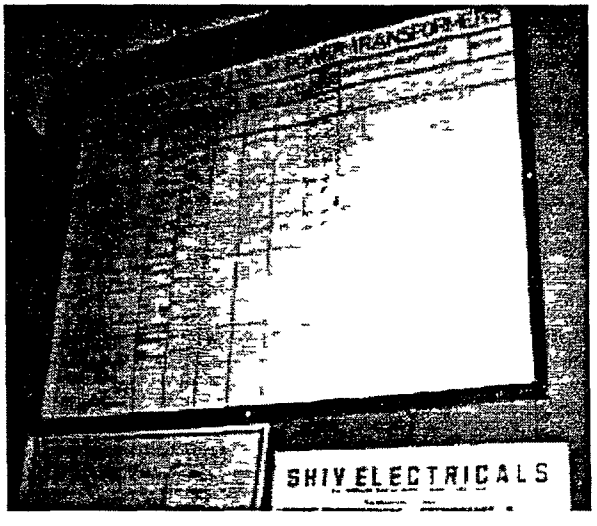


Above wire wraps are all that are used as connectors on these 415v lines Below is a typical distribution transformer substation





Above Exposed 415v cables with strand fuses Below shows a good practice of posting maintenance charts in substations



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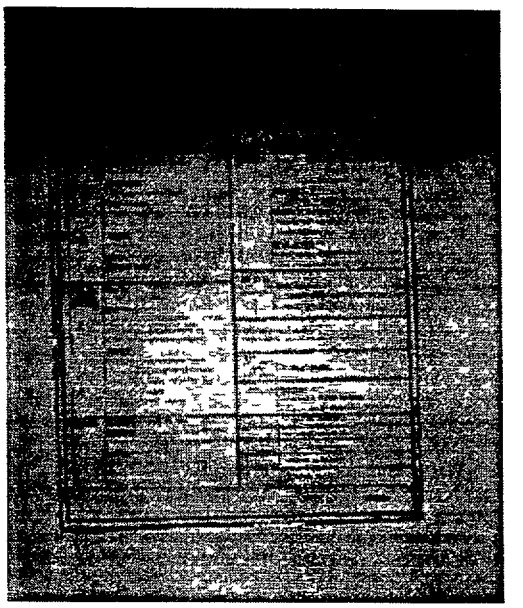
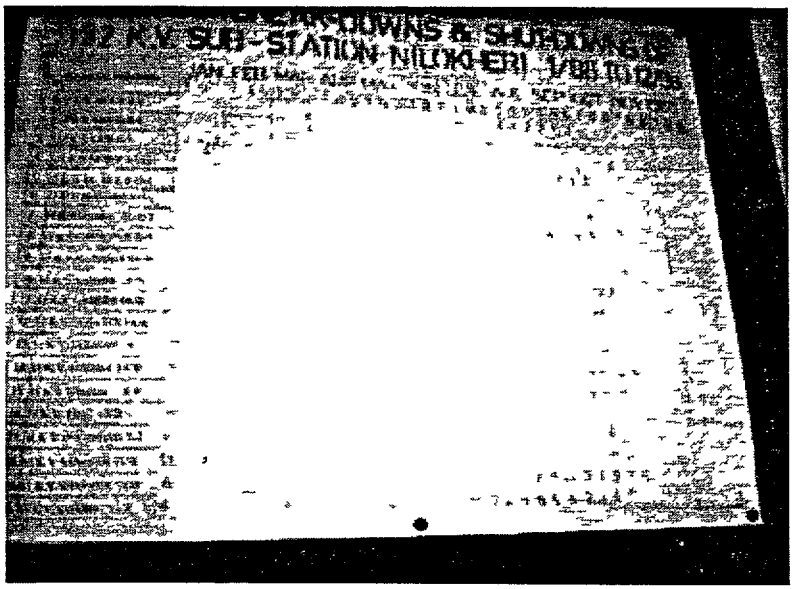
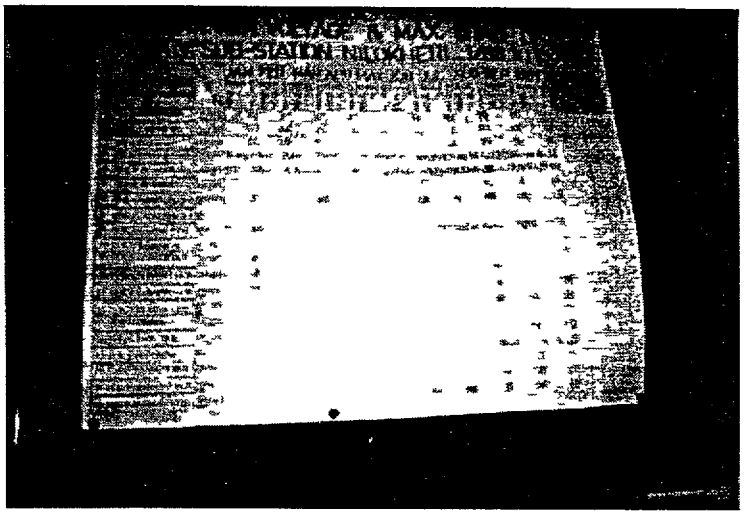
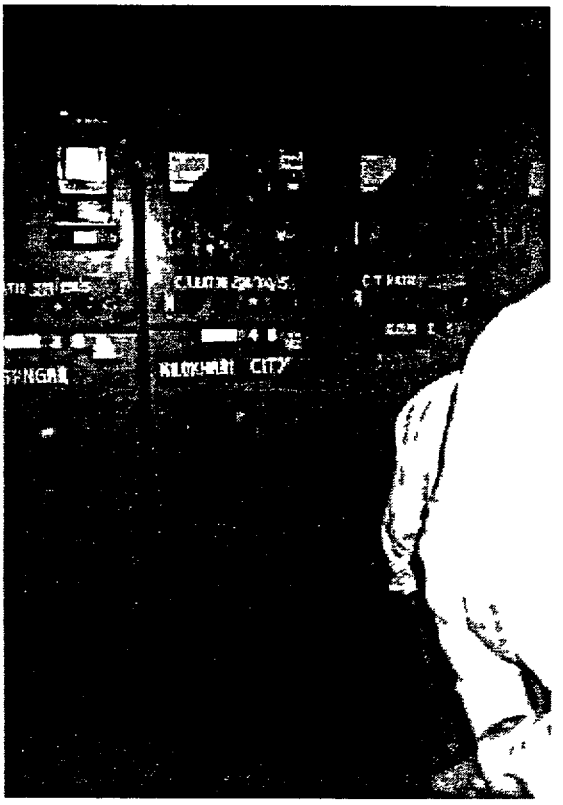


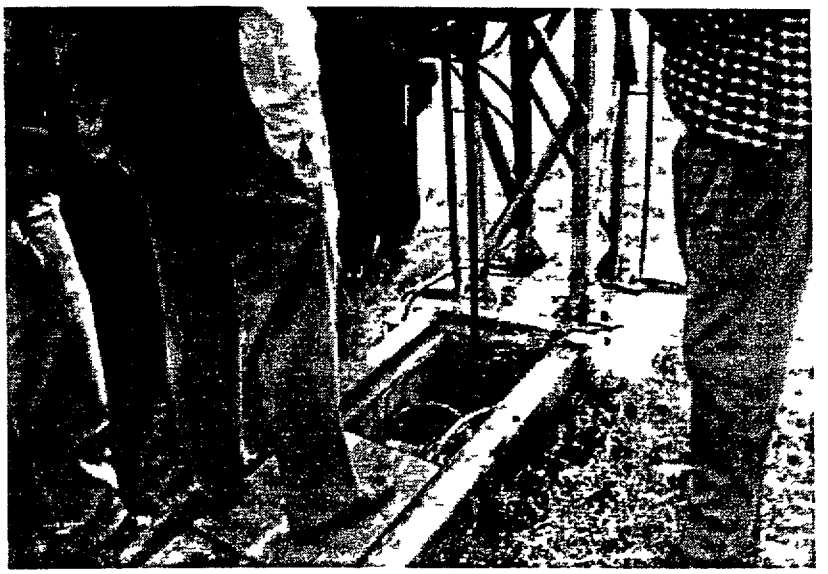
Above the substation maintenance schedule has been posted This is a good practice Below, past records of shutdowns have been posted also a good practice



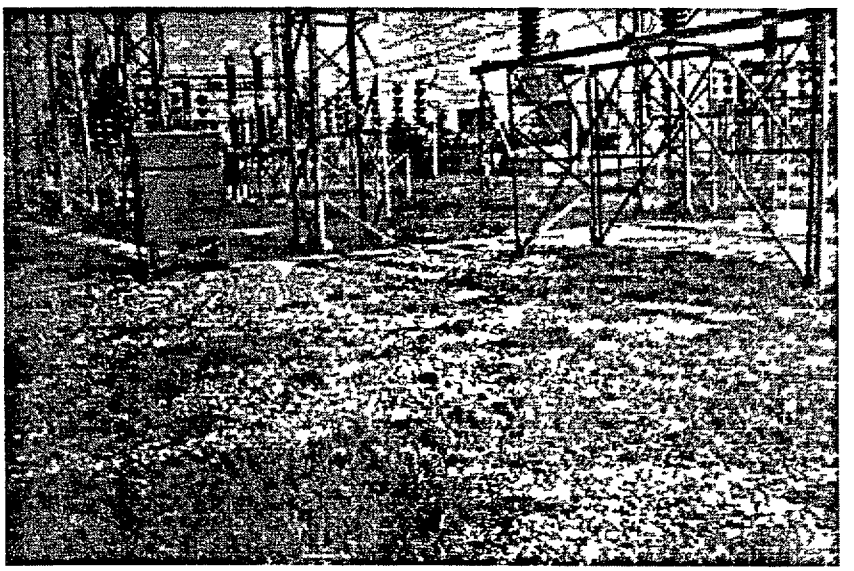


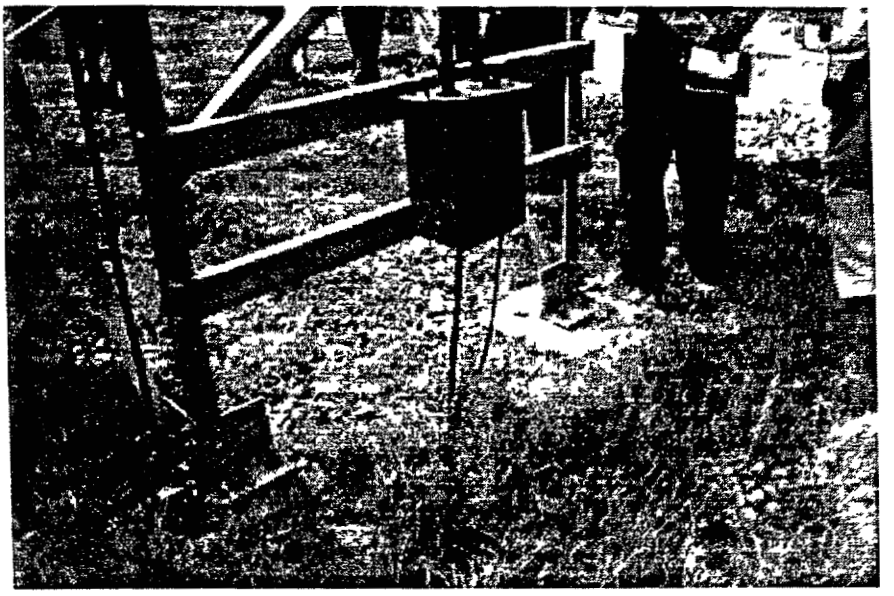
Above past records of load on the substation is posted a good practice Below many indicating lights are burnt out a very bad situation



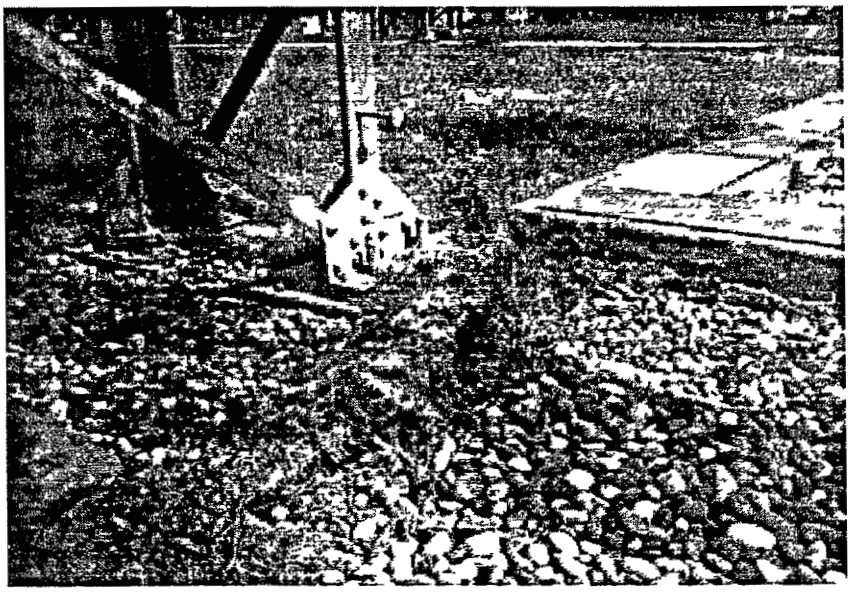


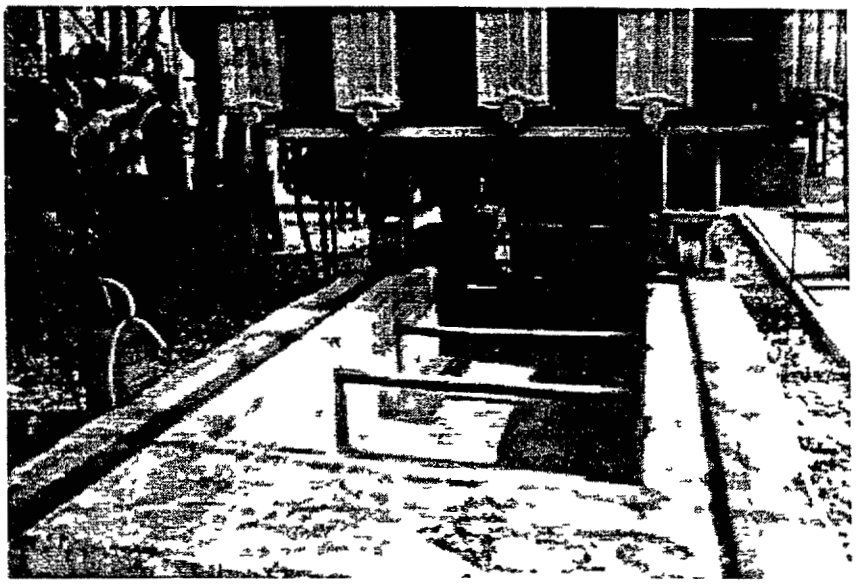
Above trenches and cables have been poorly installed and maintained
Below grass has grown in destroying the crushed rock surface



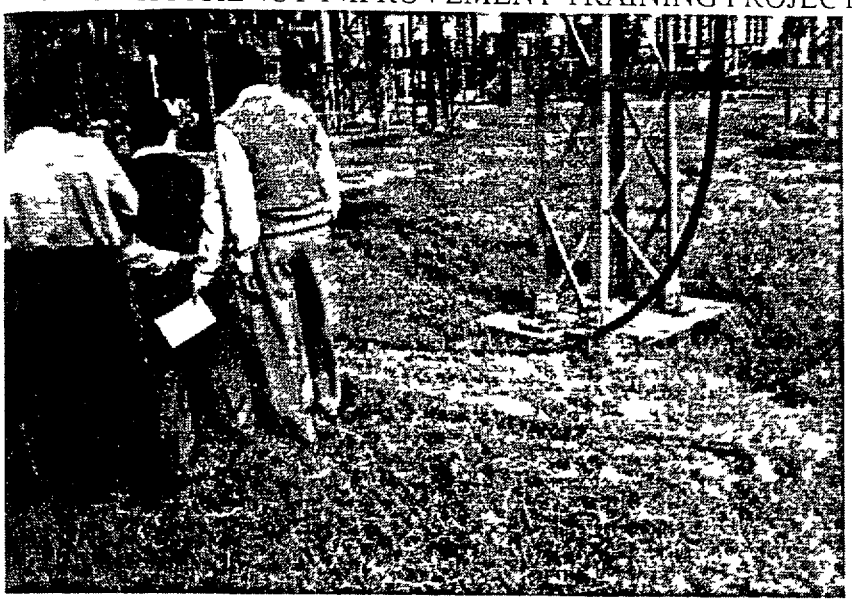


Above this control cable has been poorly installed with no conduit
Below 11 kV cables have been laid on the surface a poor but common practice

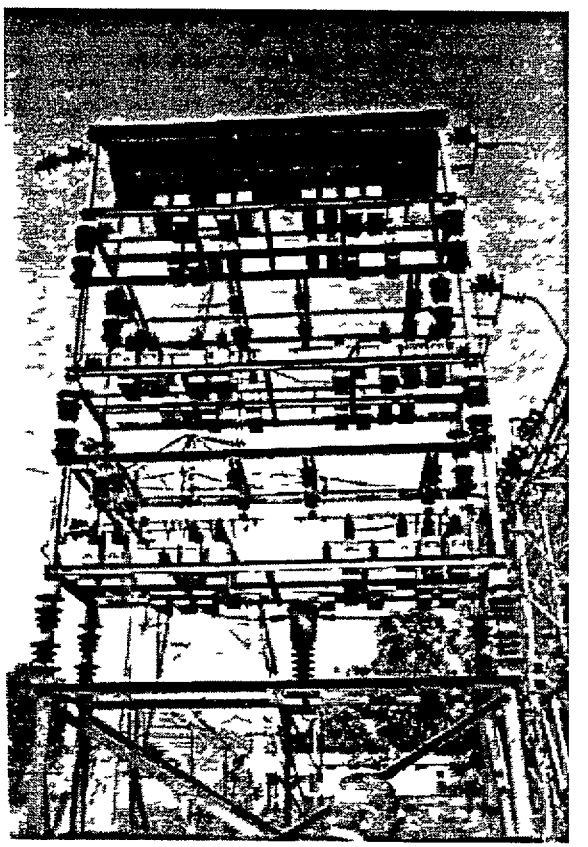


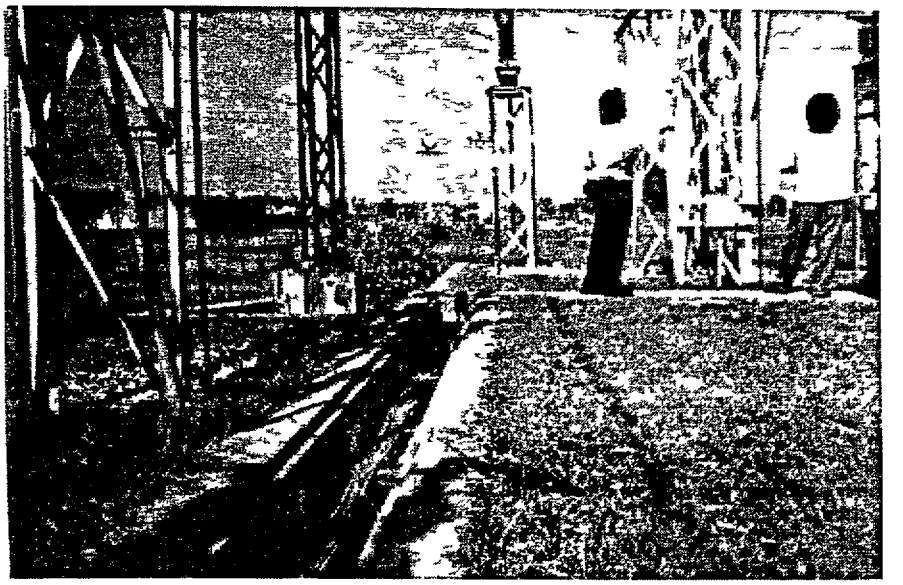


Above this transformer has no catch basin in the case of spilled oil Below control cables have been haphazardly lain on the ground

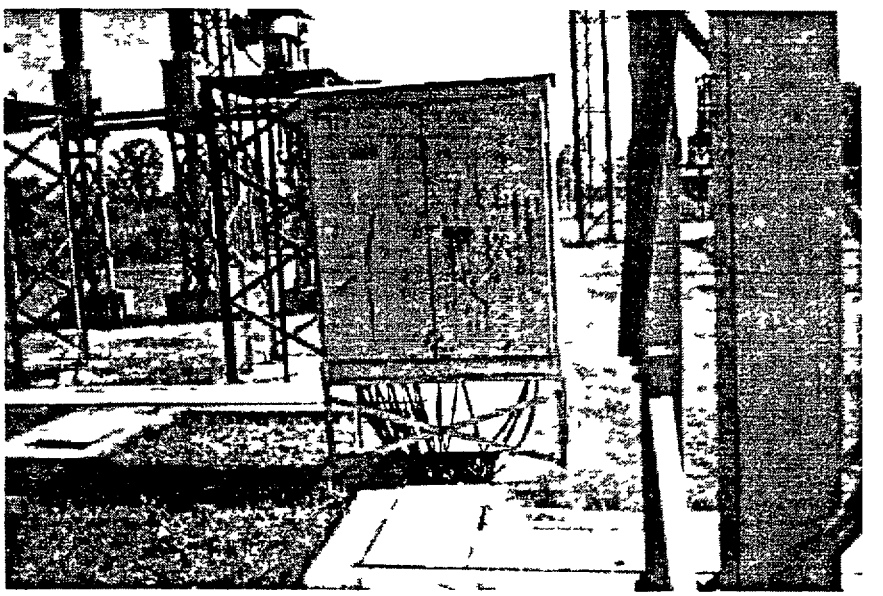


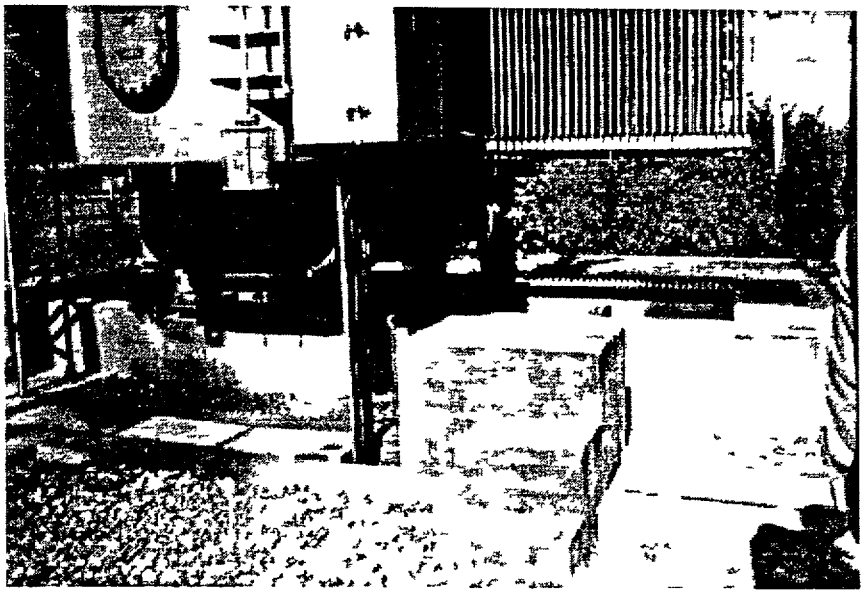
Above 11kV cables are running along the ground not buried in trenches as they should Below this capacitor bank has been vandalized



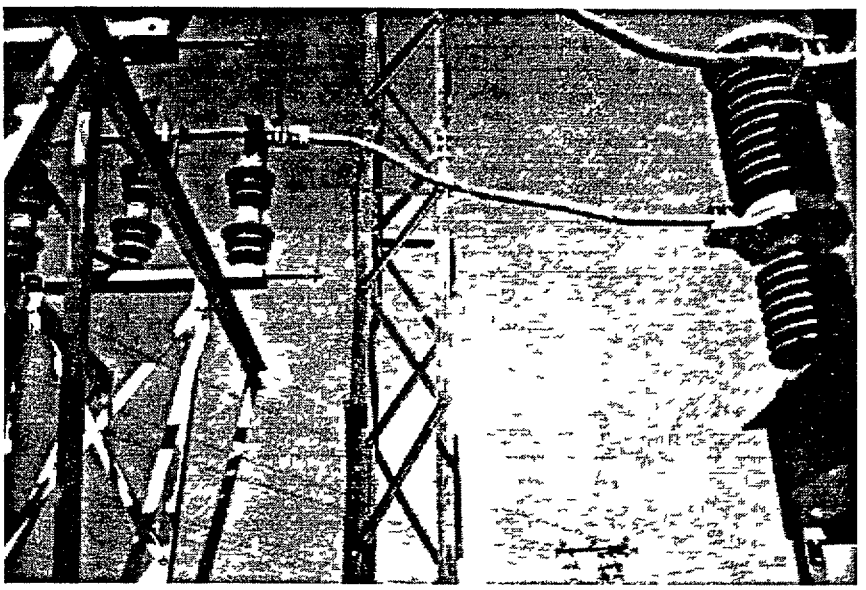


Above leaving a trench open as this has been is a poor practice Below corroded kiosks with cables entering without the protection of conduit pose a reliability problem.

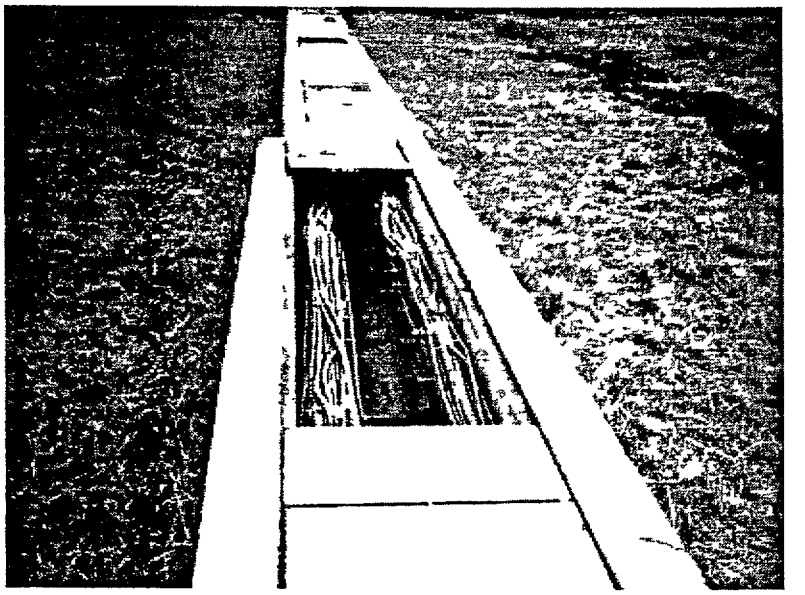




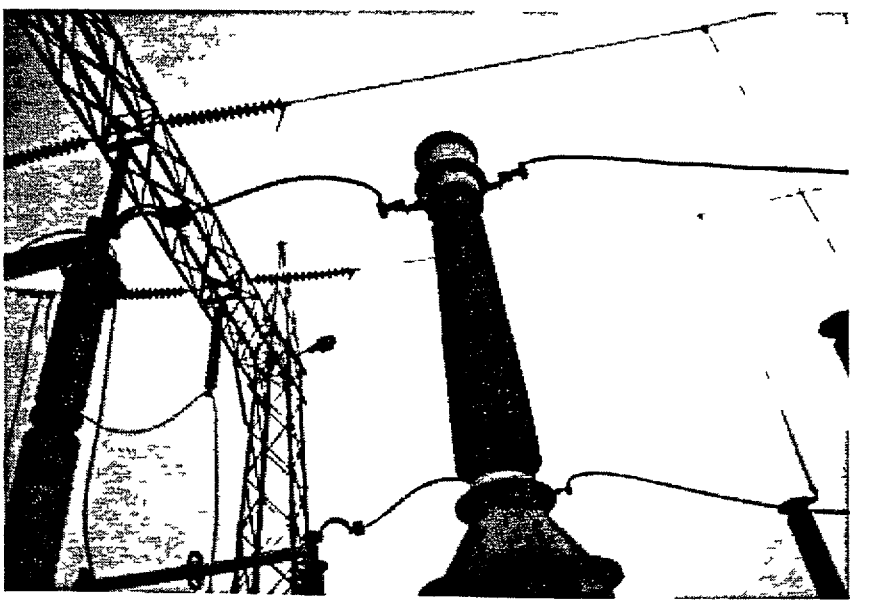
Above These cable entering the transformer don t have the protection of conduit Below the strands of these jumpers are opening



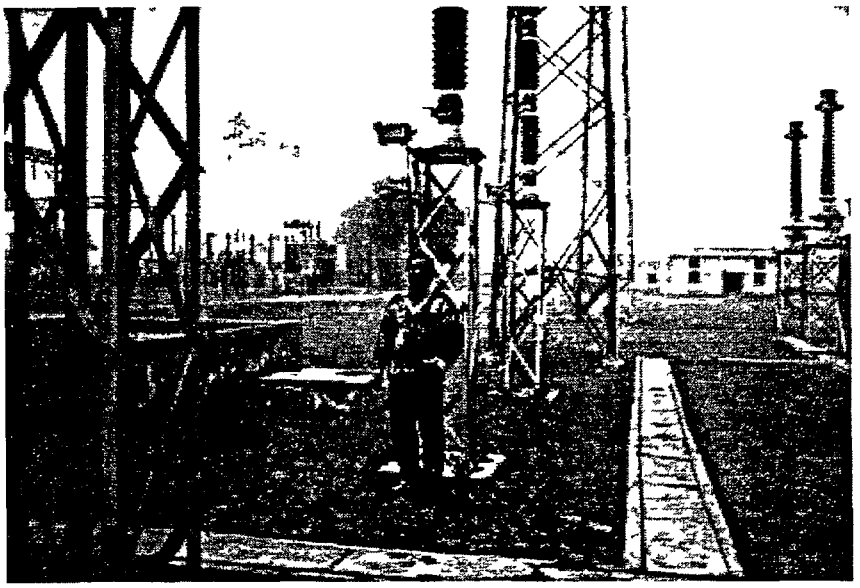
Above this marshalling kiosk is corroded and has no gaskets on the doors Below these cable are exposed to sunlight and other harmful elements because the trench covers are missing

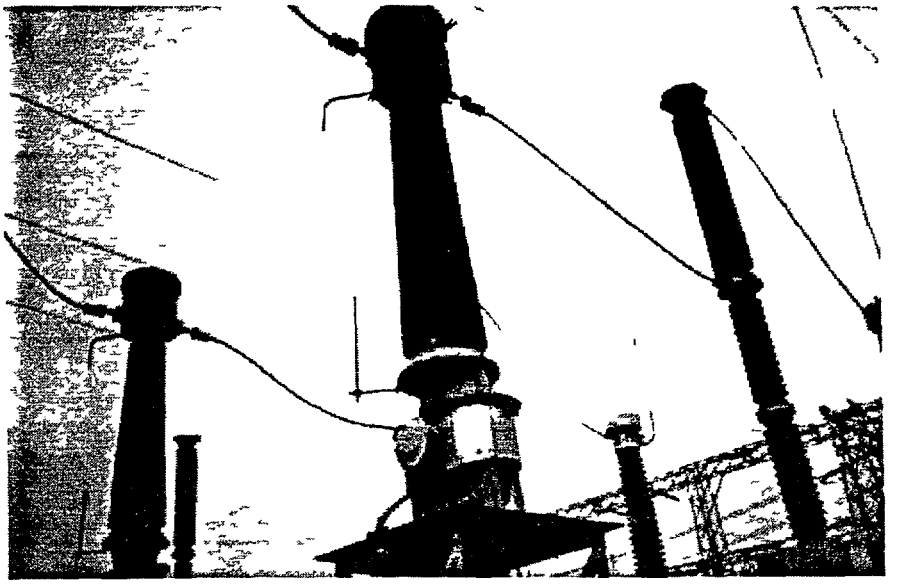


Above birds have formed nests inside the corona rings of these isolator switches Below horizontal connectors are needed to reduce the bending radius on the jumpers

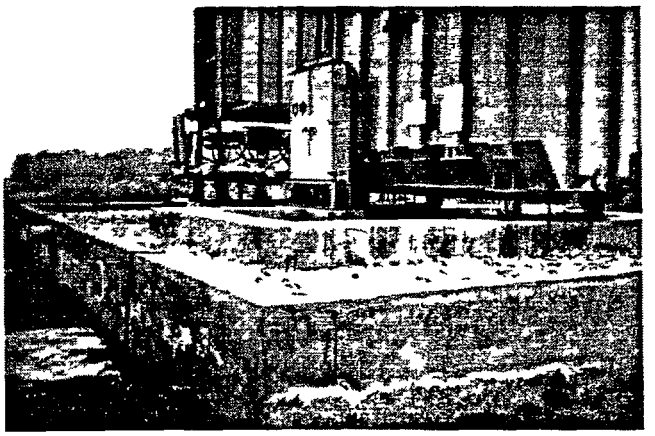


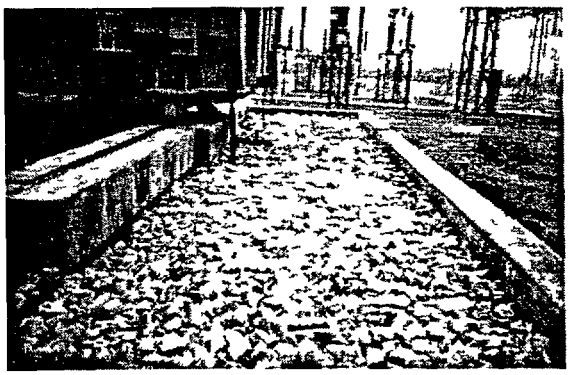
Above horizontal connectors are needed to reduce the bending radius on these jumpers Below these surge counters have been mounted too high and are difficult to read



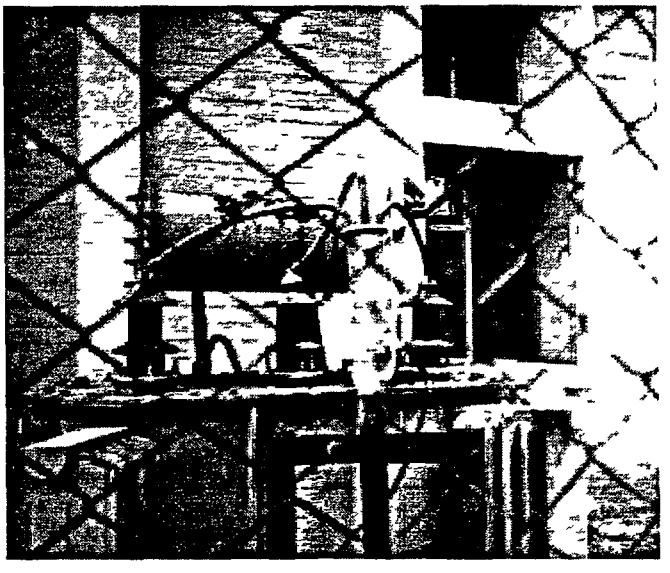


Above these arcing rods are not aligned Below a well designed and installed oil catch basin and transformer foundation



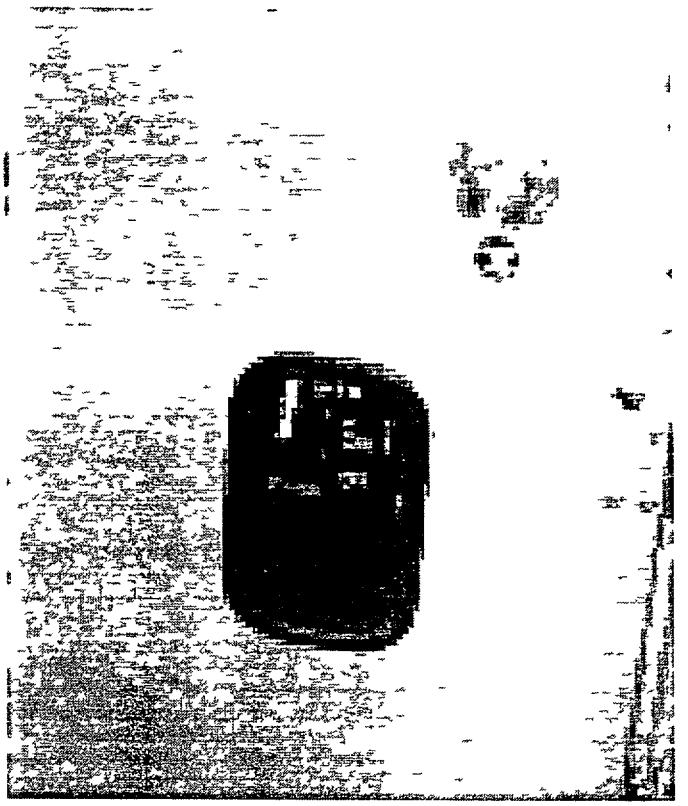


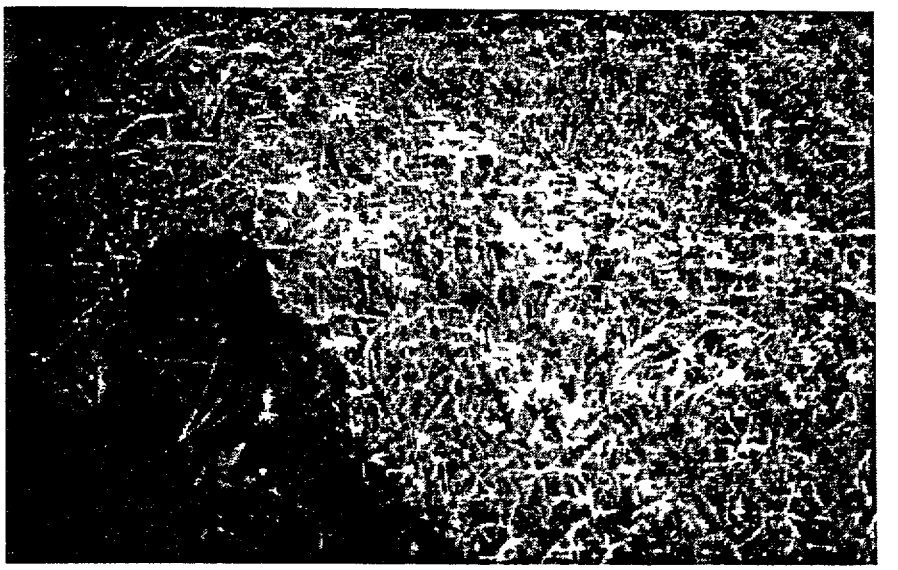
This station service transformer is supplied by a poorly designed pothead The clearances are not adequate between live 11 kV phases



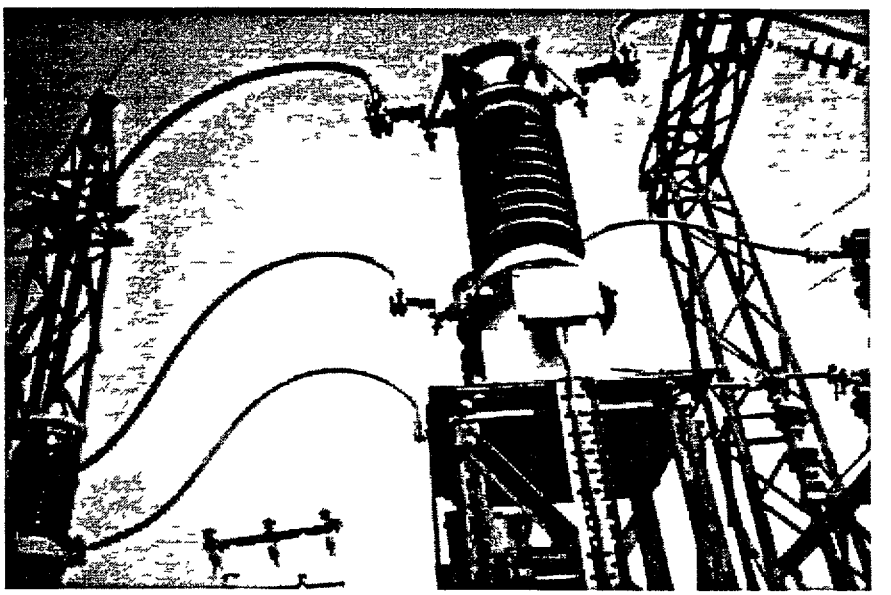
Right The position of this 11kV breaker can not be determined by the indicator ON and OFF are both displayed in the window Below

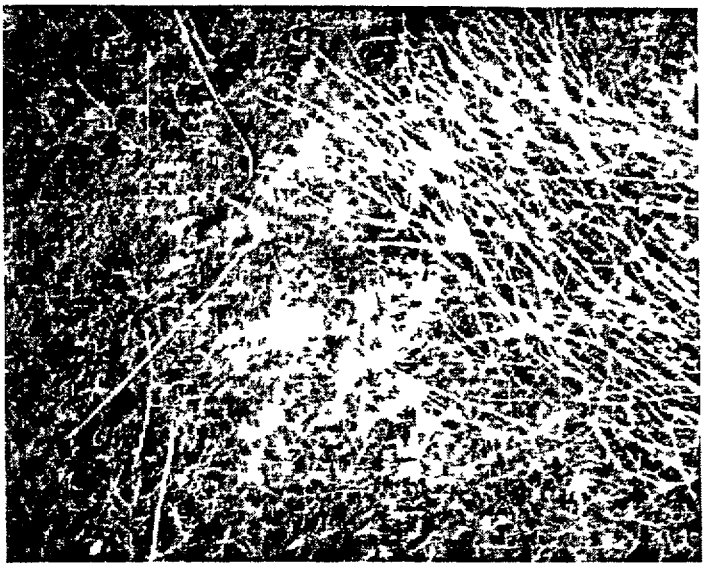
these battery calble have no fuses



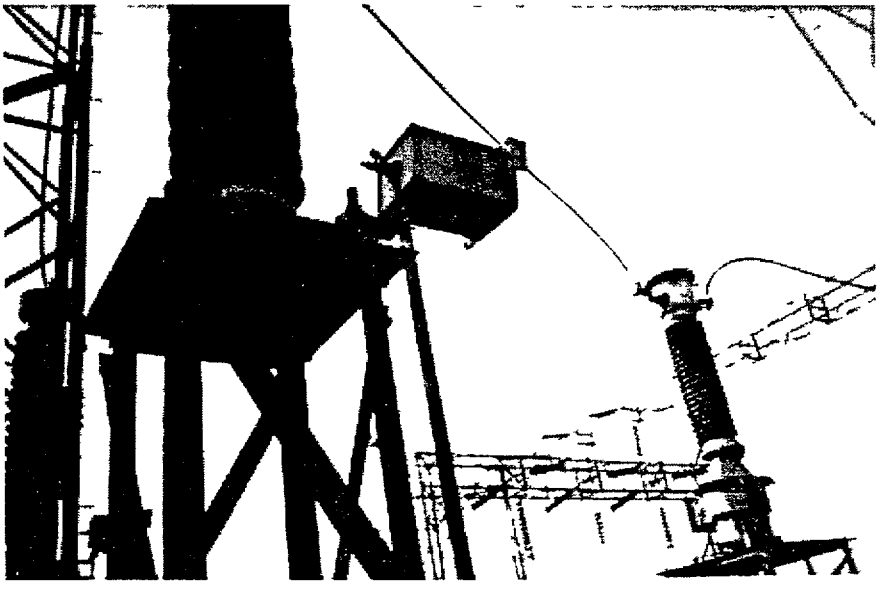


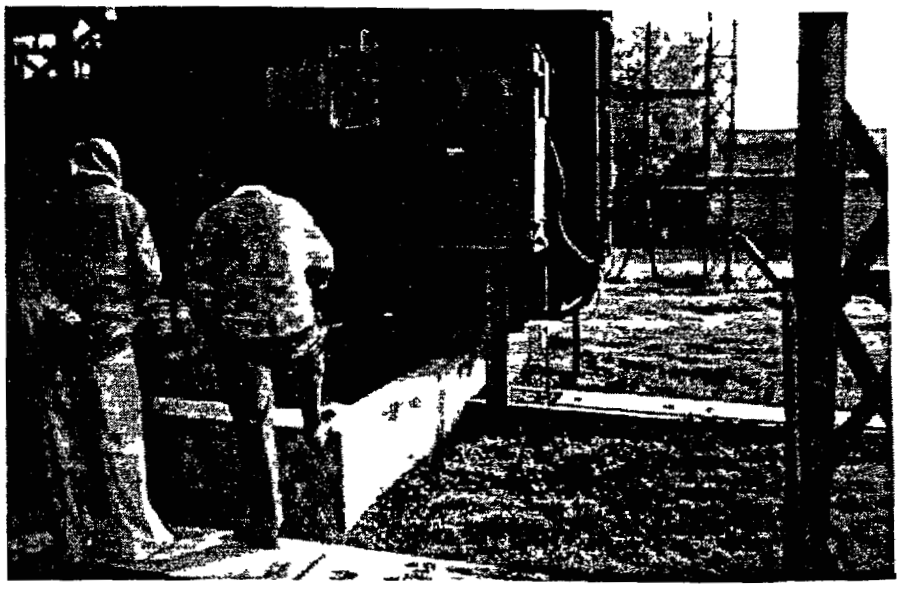
Above these 11 kV cables are laying on the ground not buried Below these jumpers should be connected with horizontal connectors



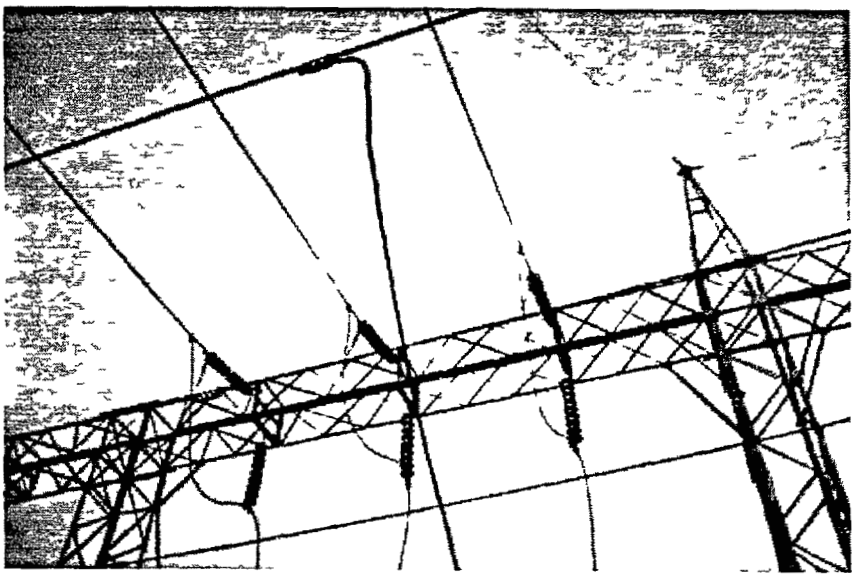


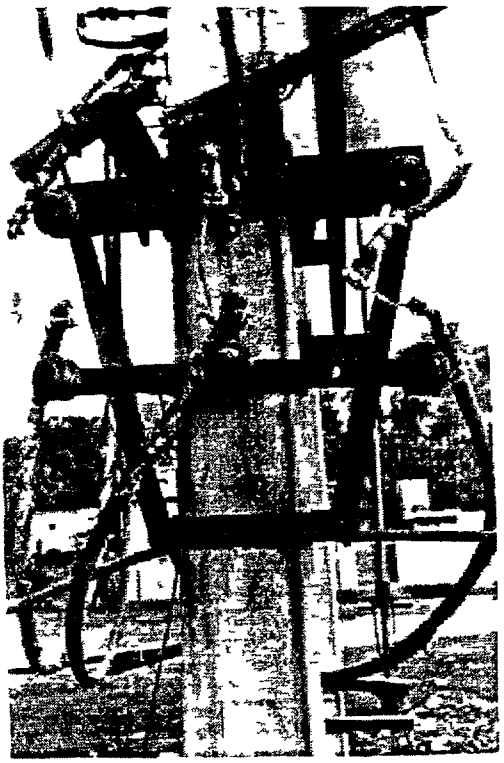
Above this is a poor practice of laying electrical lines along the ground Below the surge monitors are mounted too high and can not be easily read



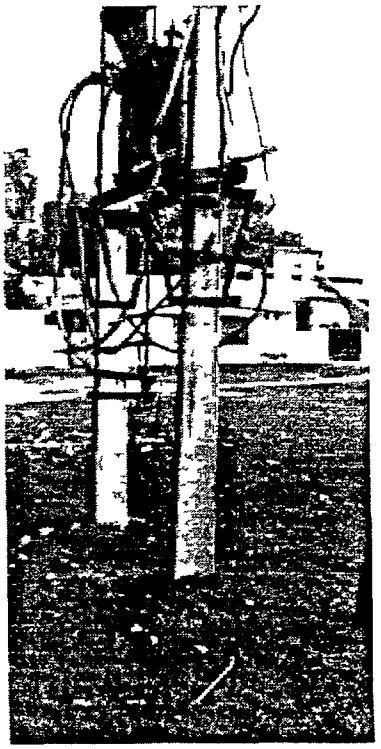


Above this transformer foundation is of a poor design
Below This connector should have been of the 'T type eliminating this sharp bend

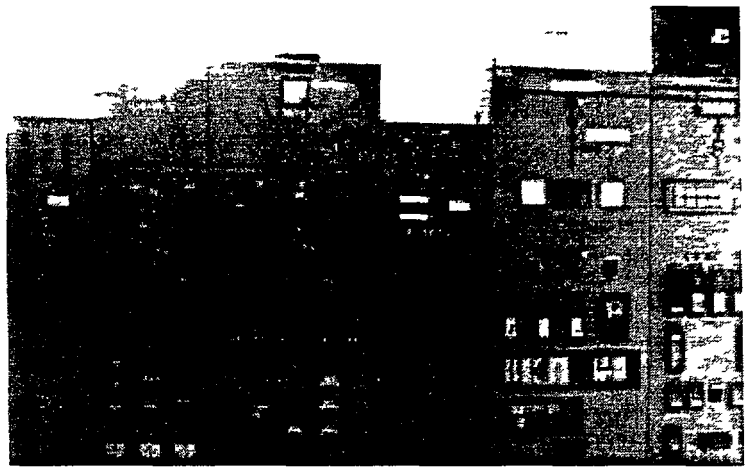


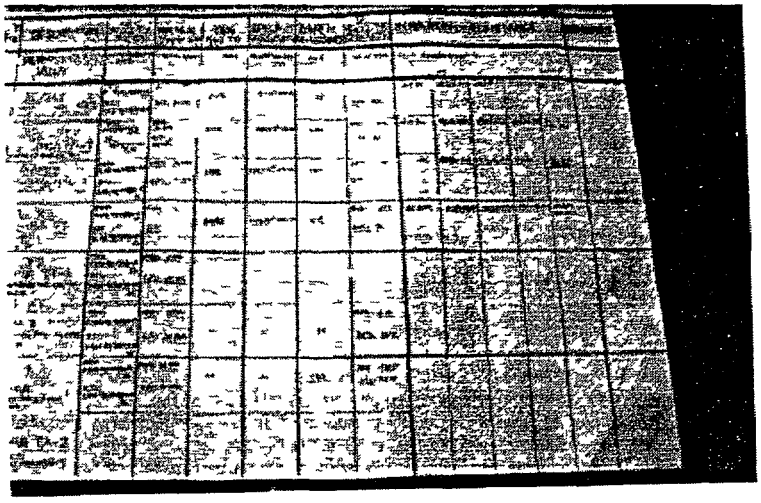


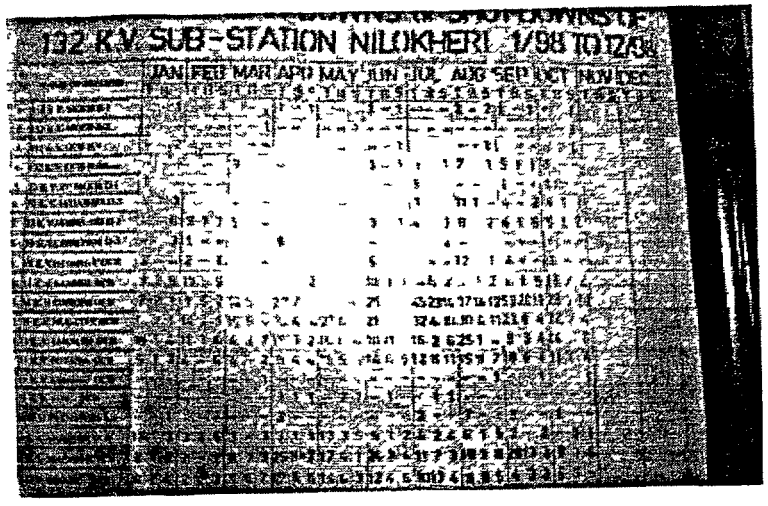
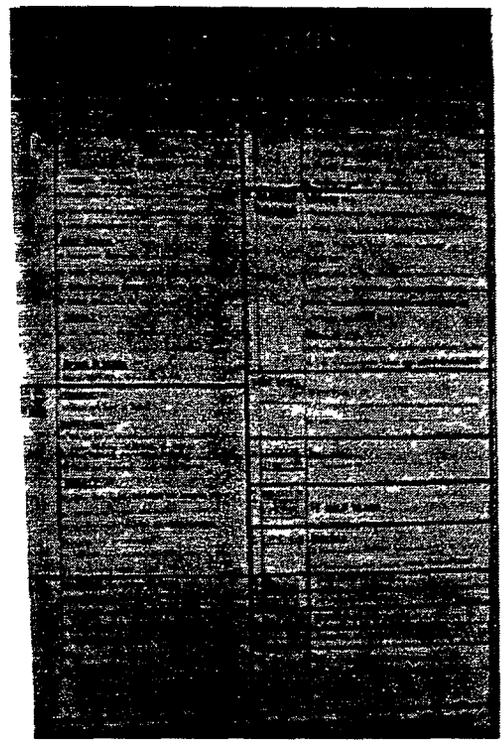
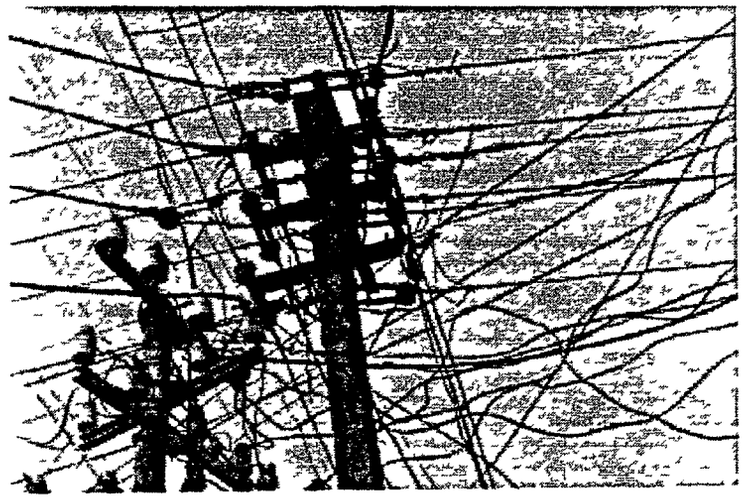
Above exposed 415v wires Below exposed 415v wires are mounted very low.



Top Mimic bus does not line up Middle and Bottom A good practice of posting the substation maintenance schedules and test results







Top A good practice of posting the substation s maintenance schedule Below wire wraps are used as connectors and can be the source of hot spots