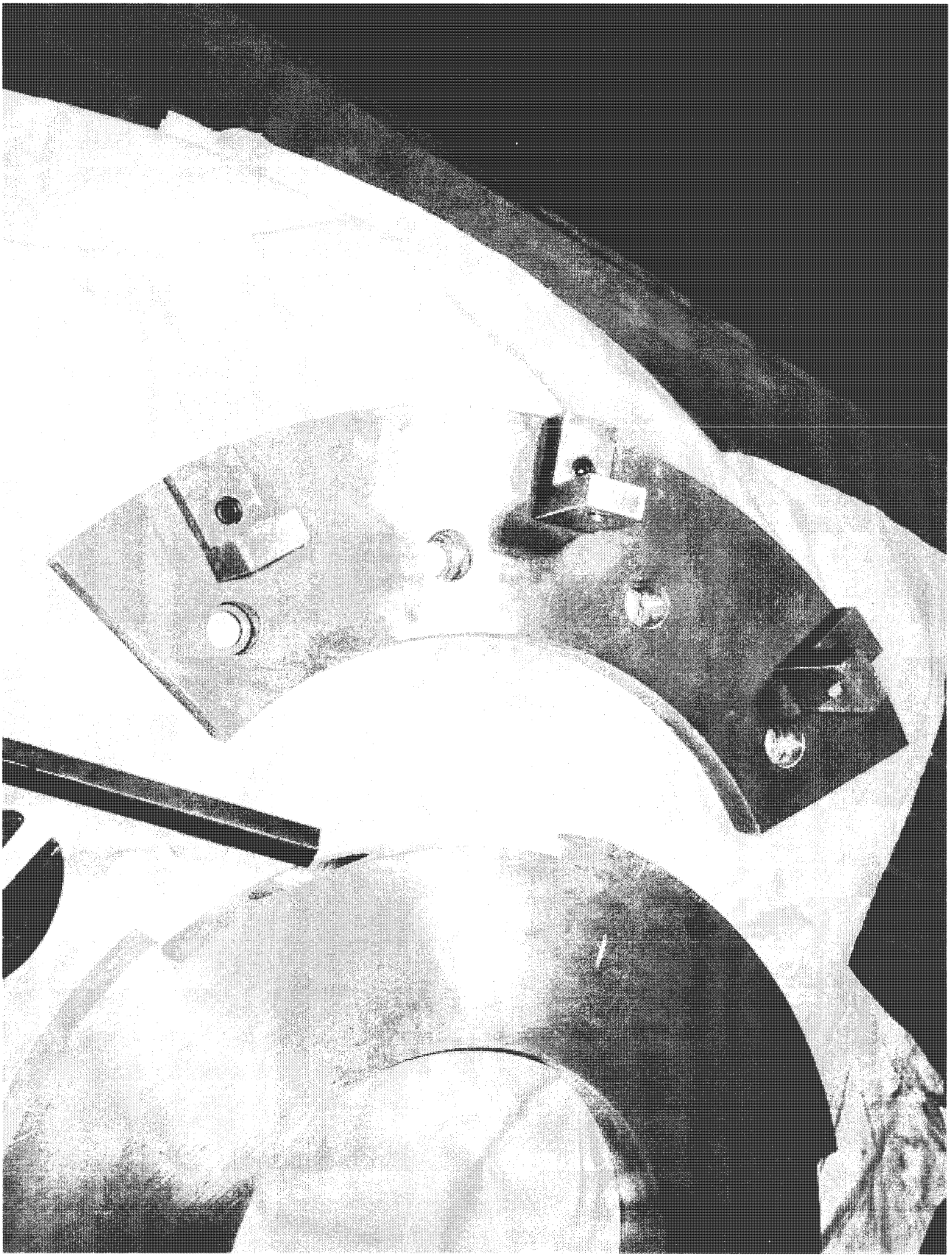

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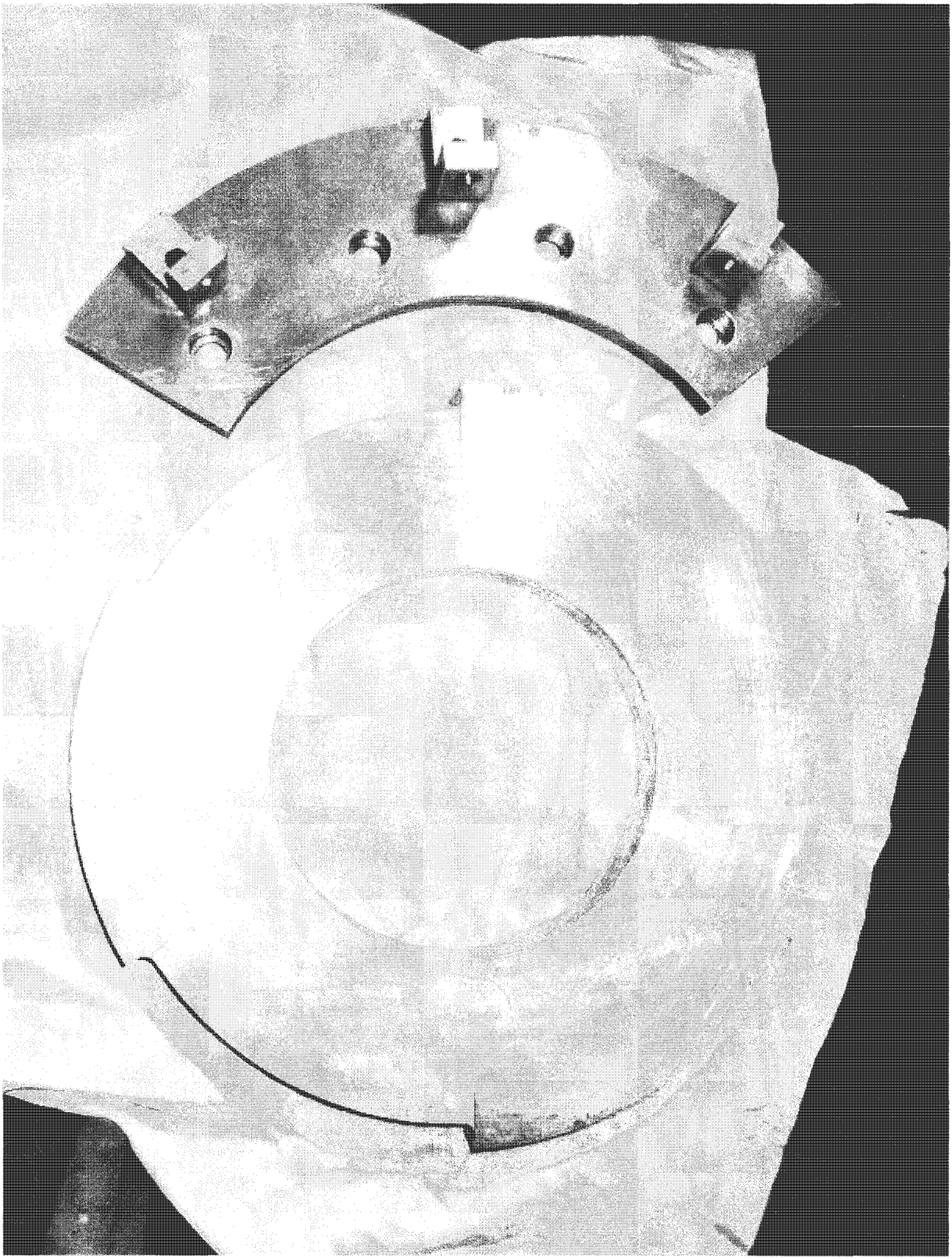

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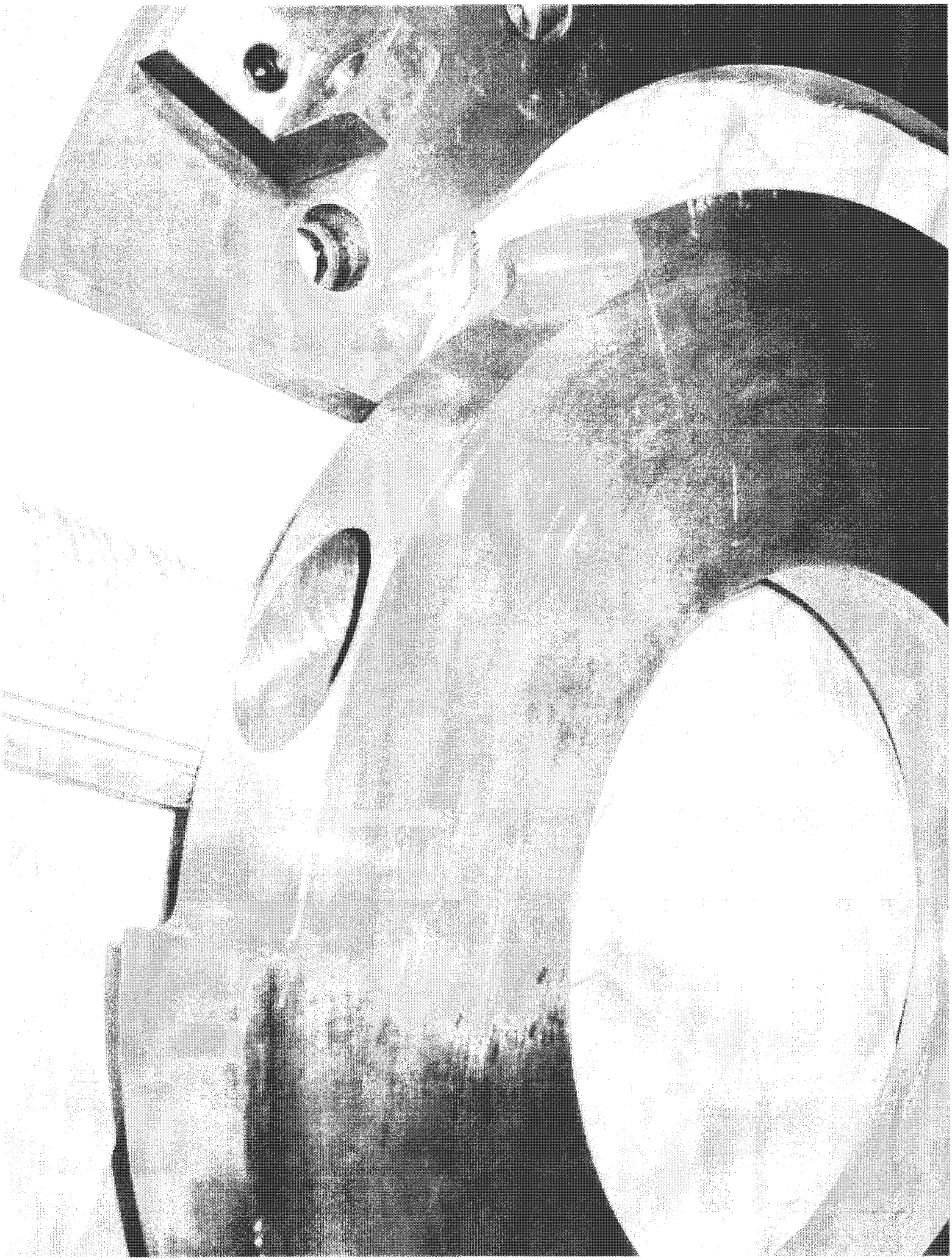

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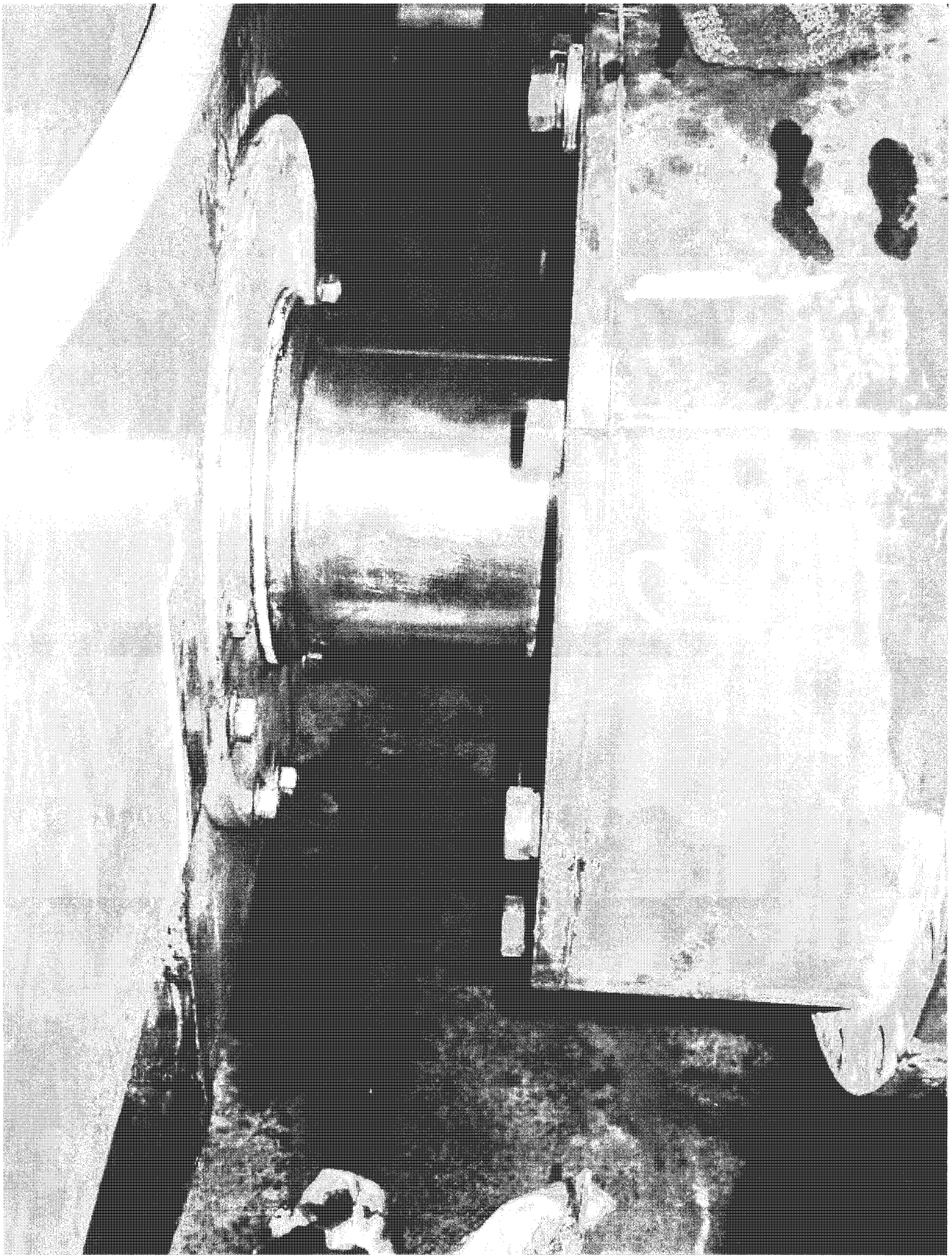

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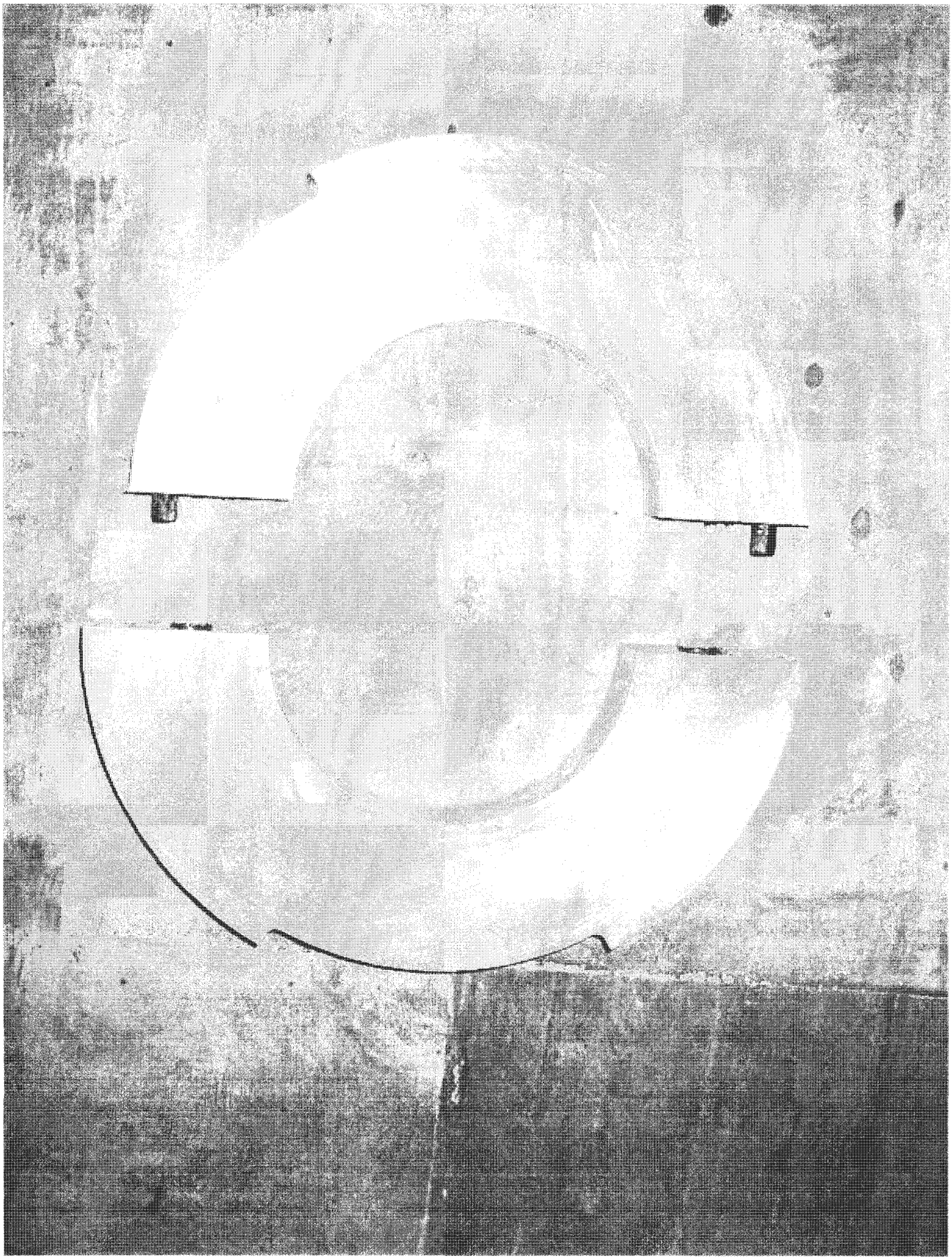

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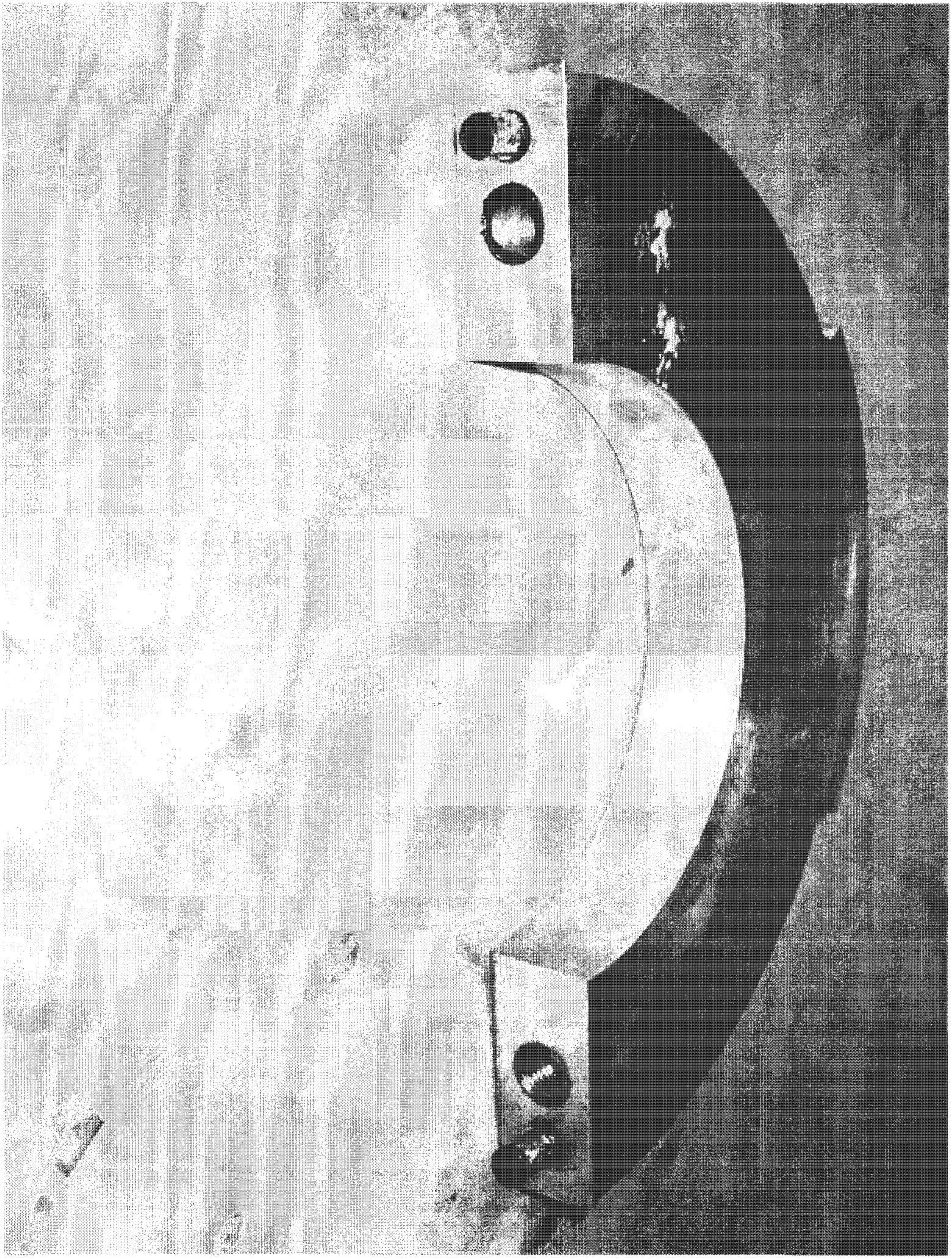

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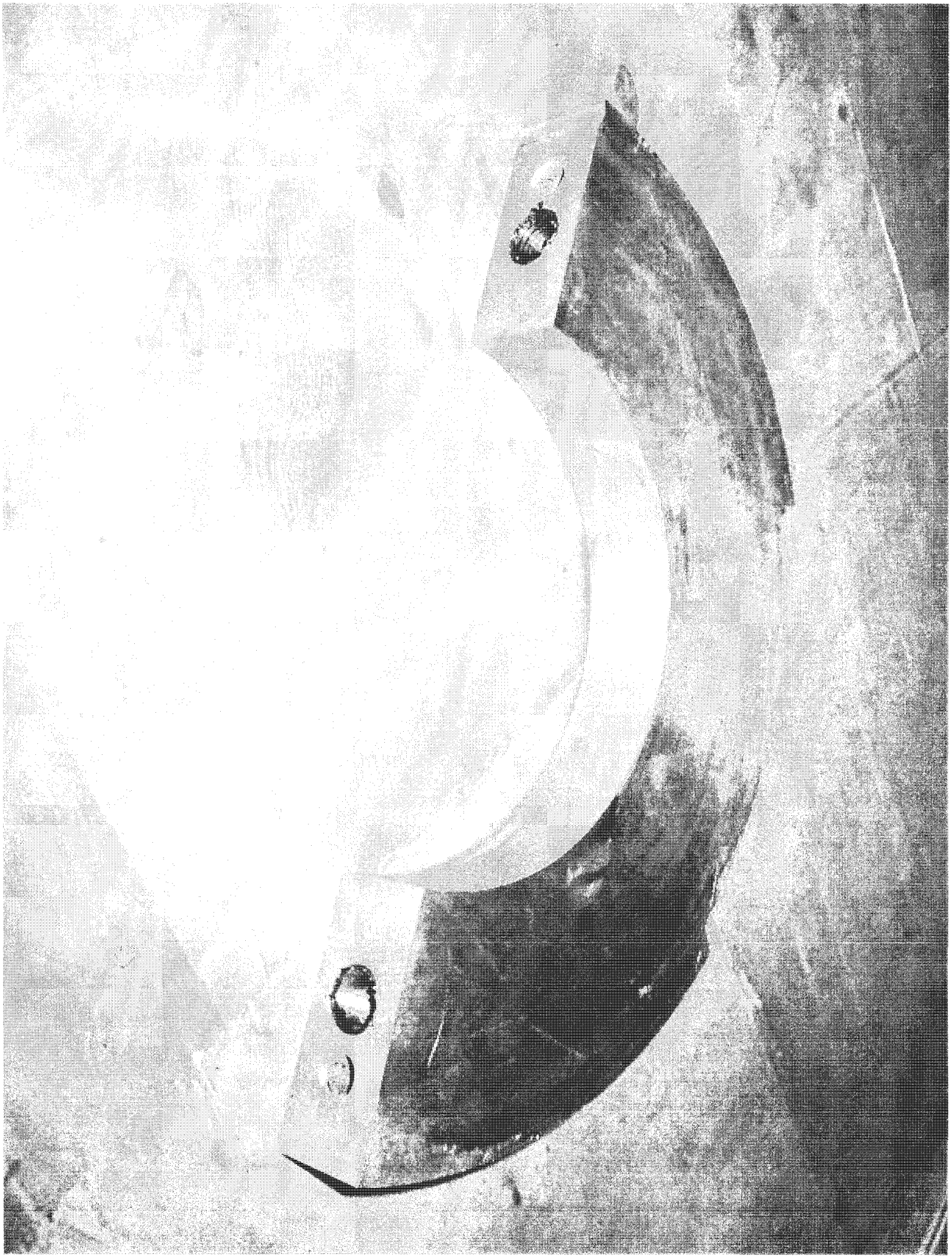

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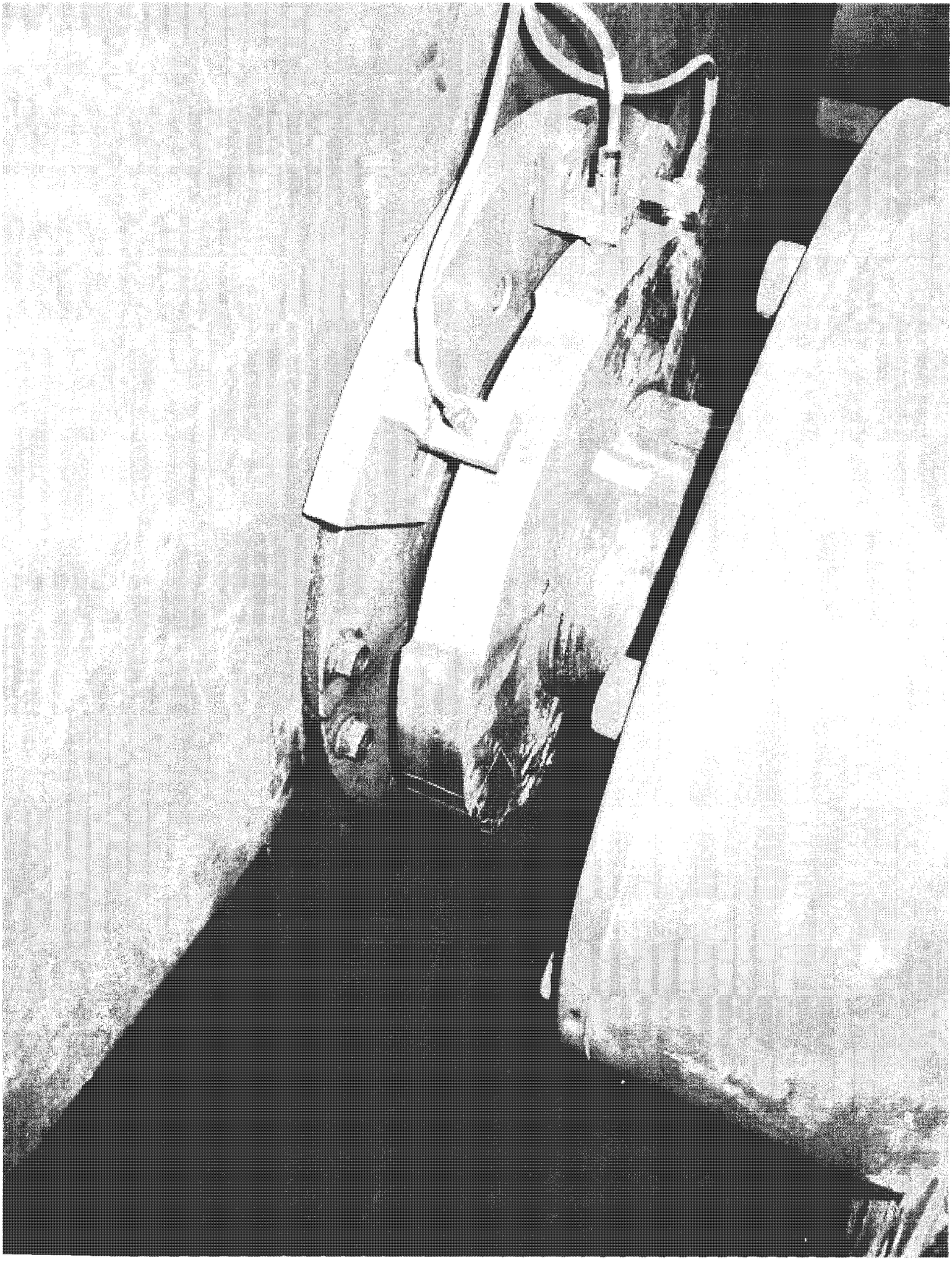

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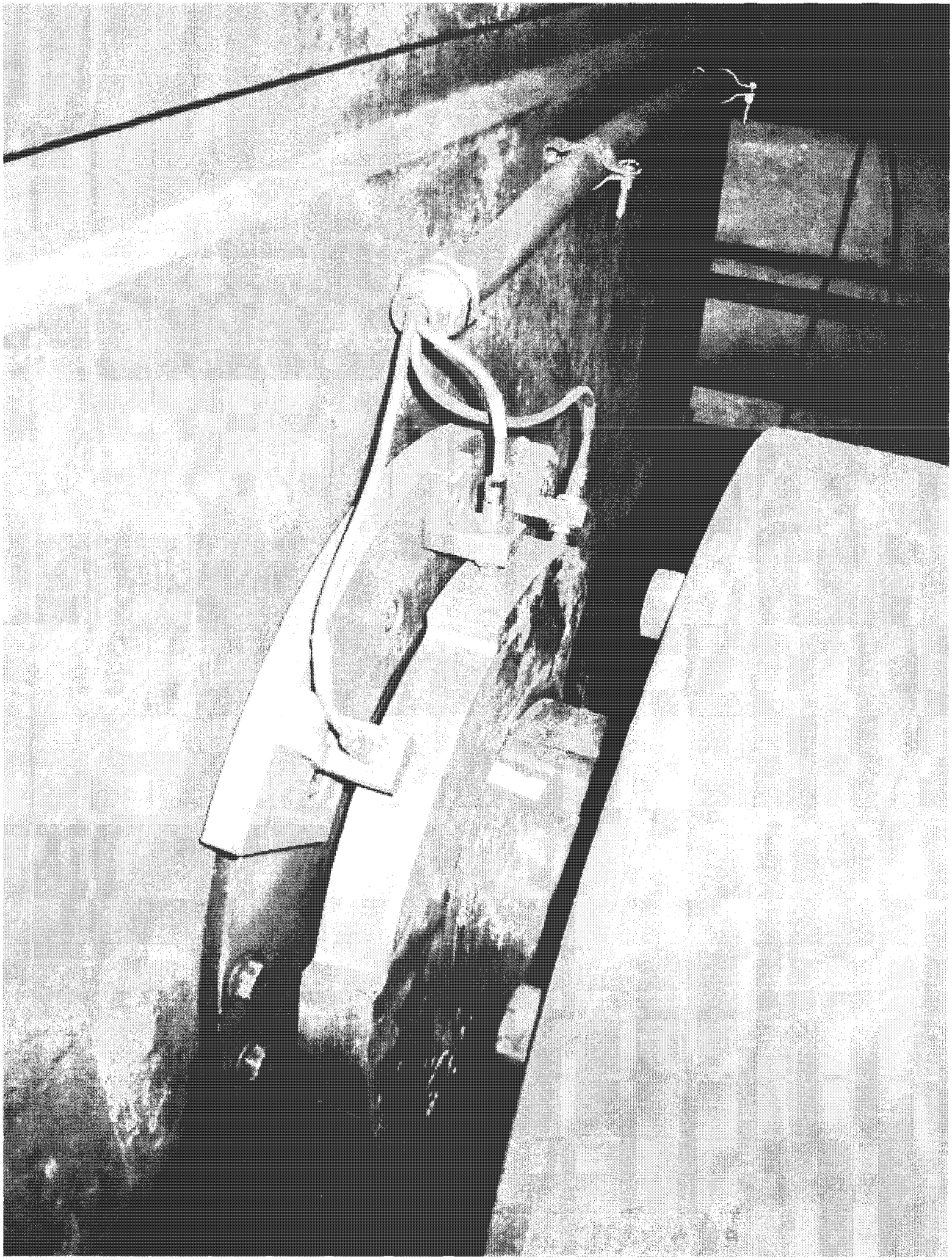

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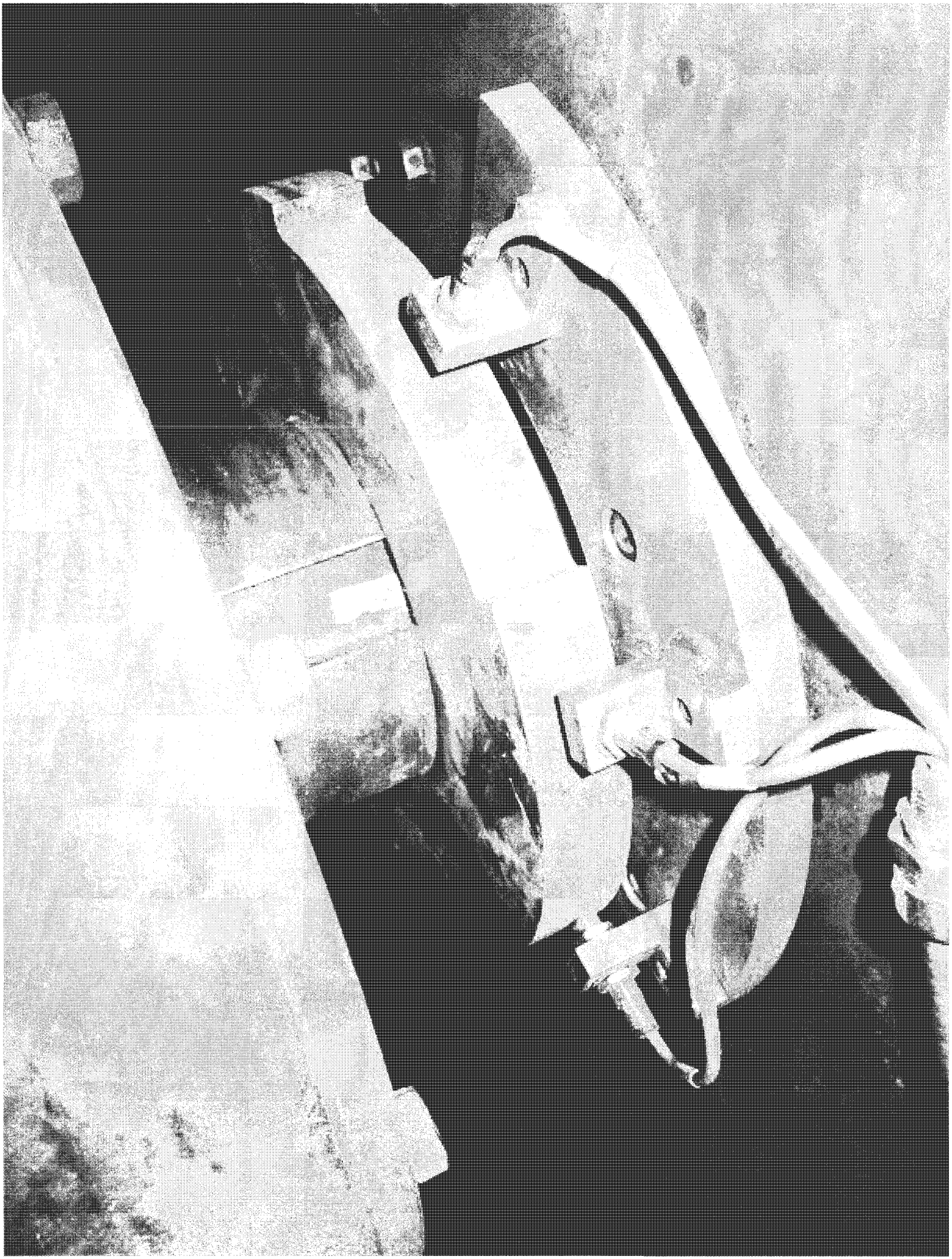

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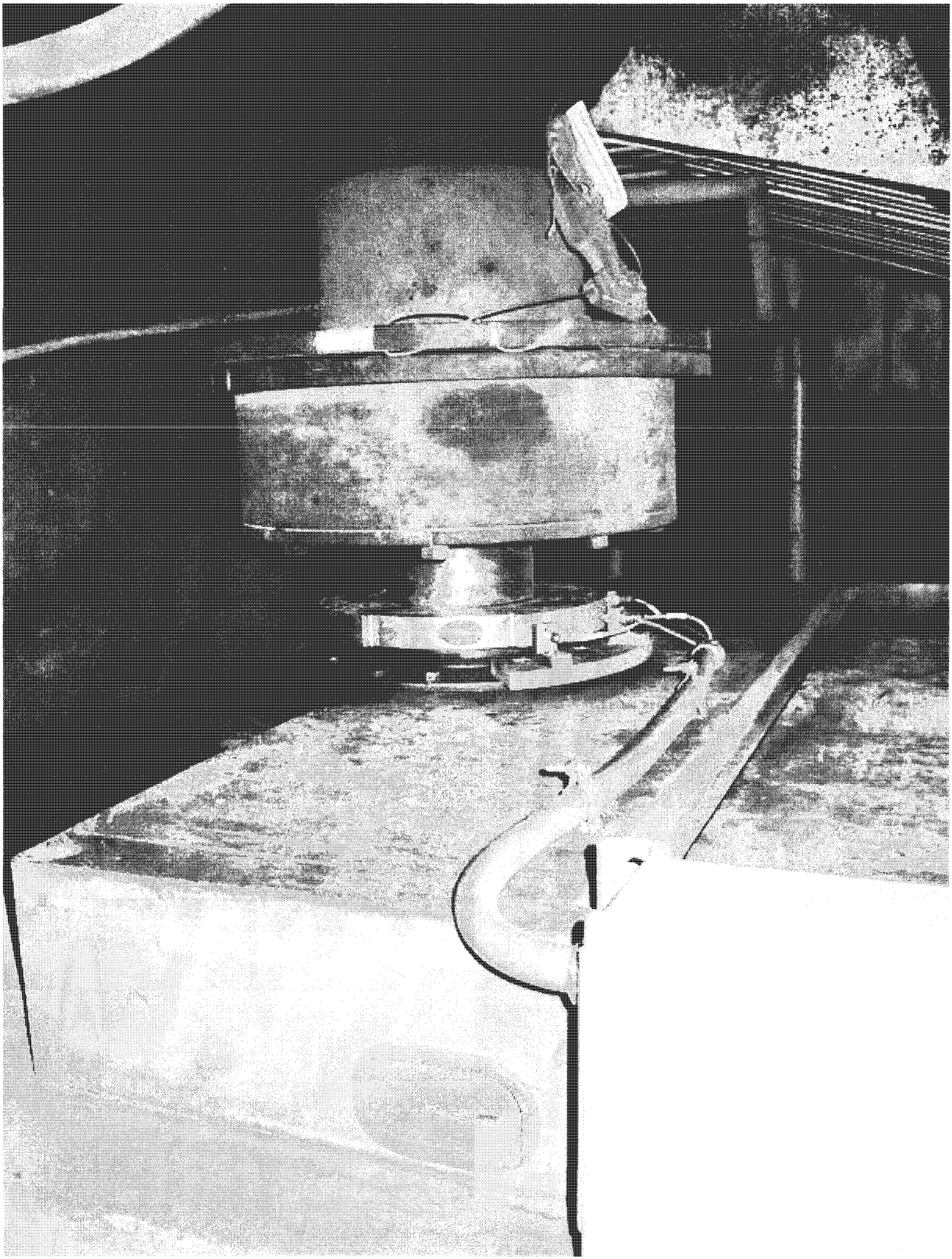

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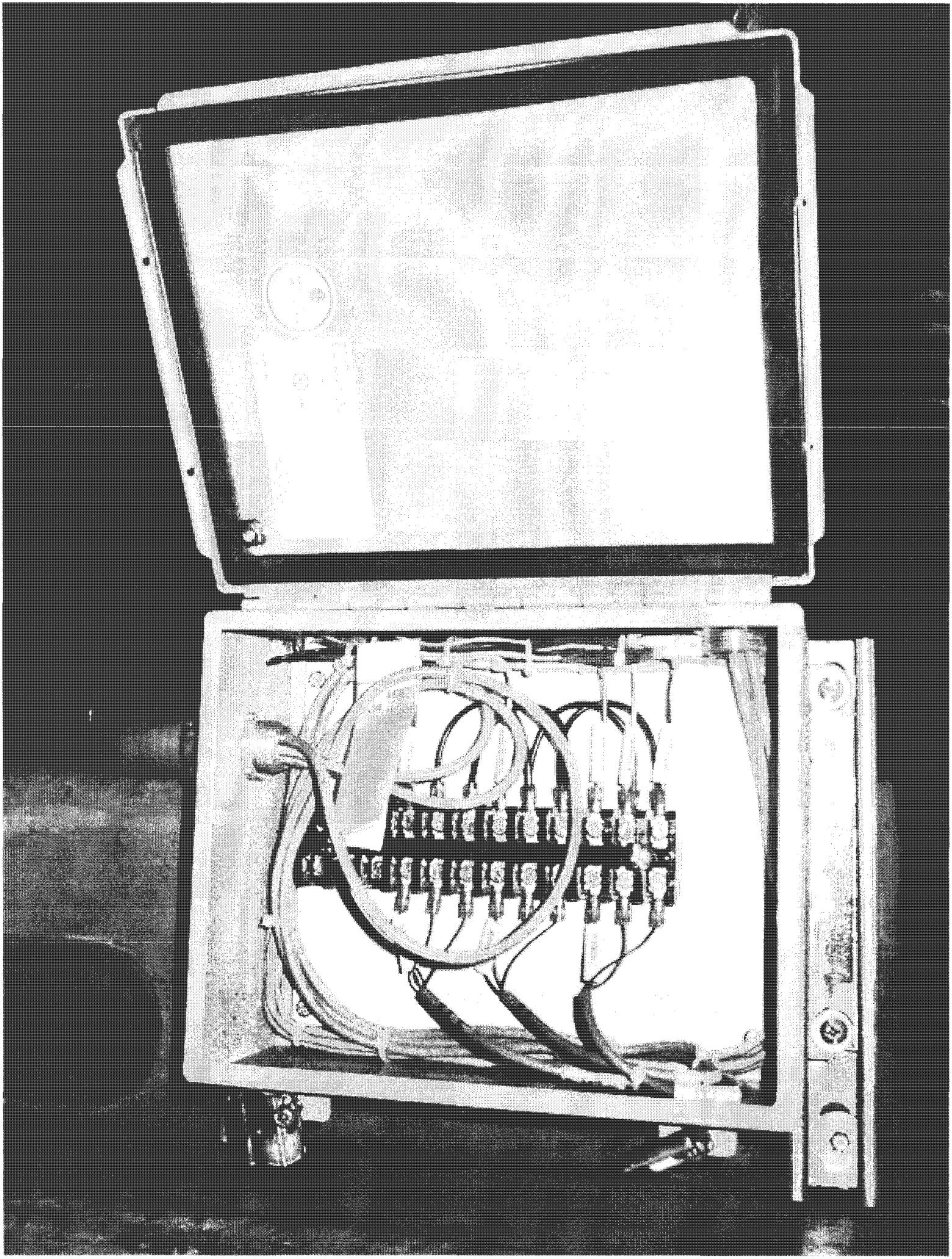

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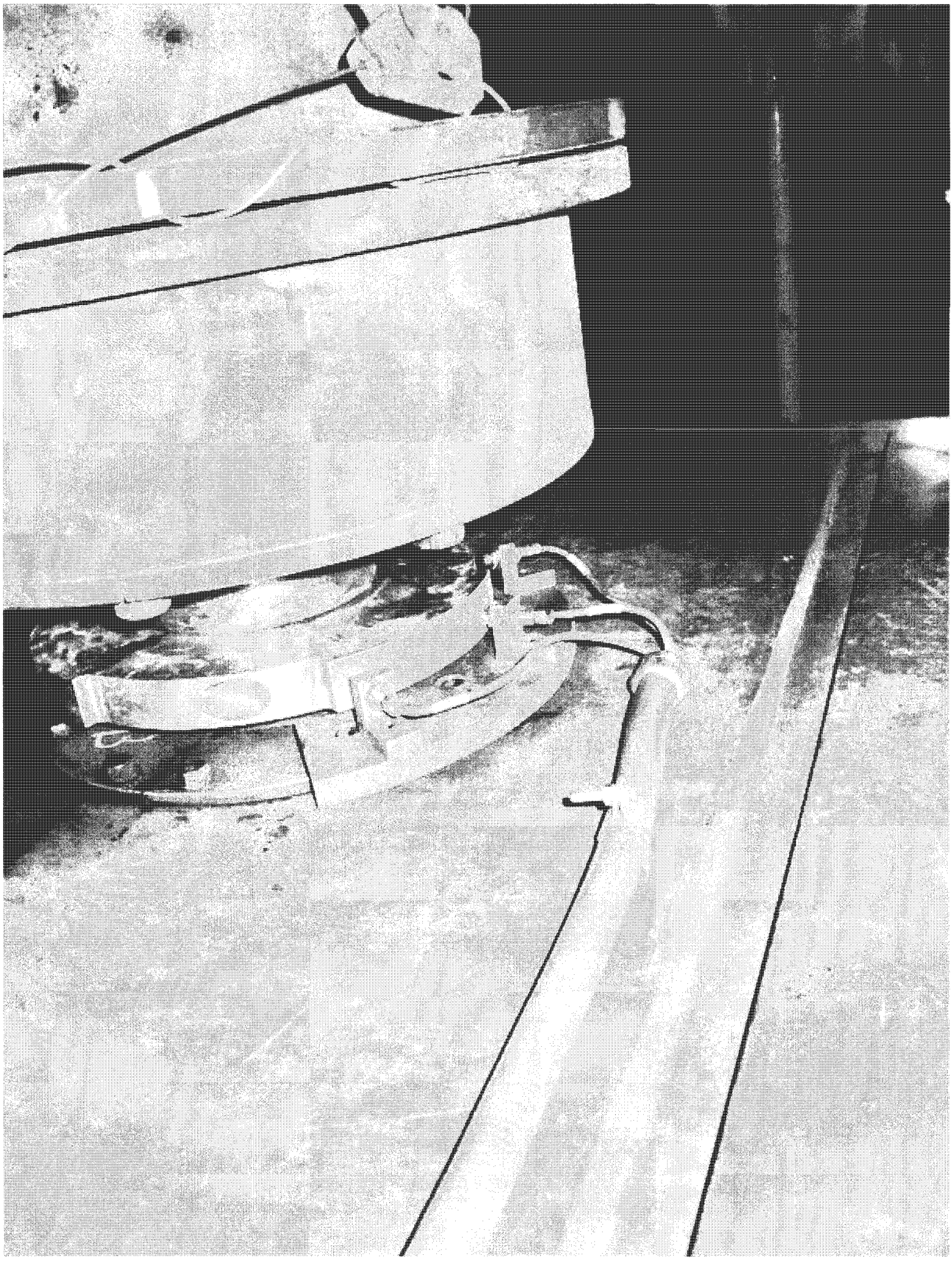

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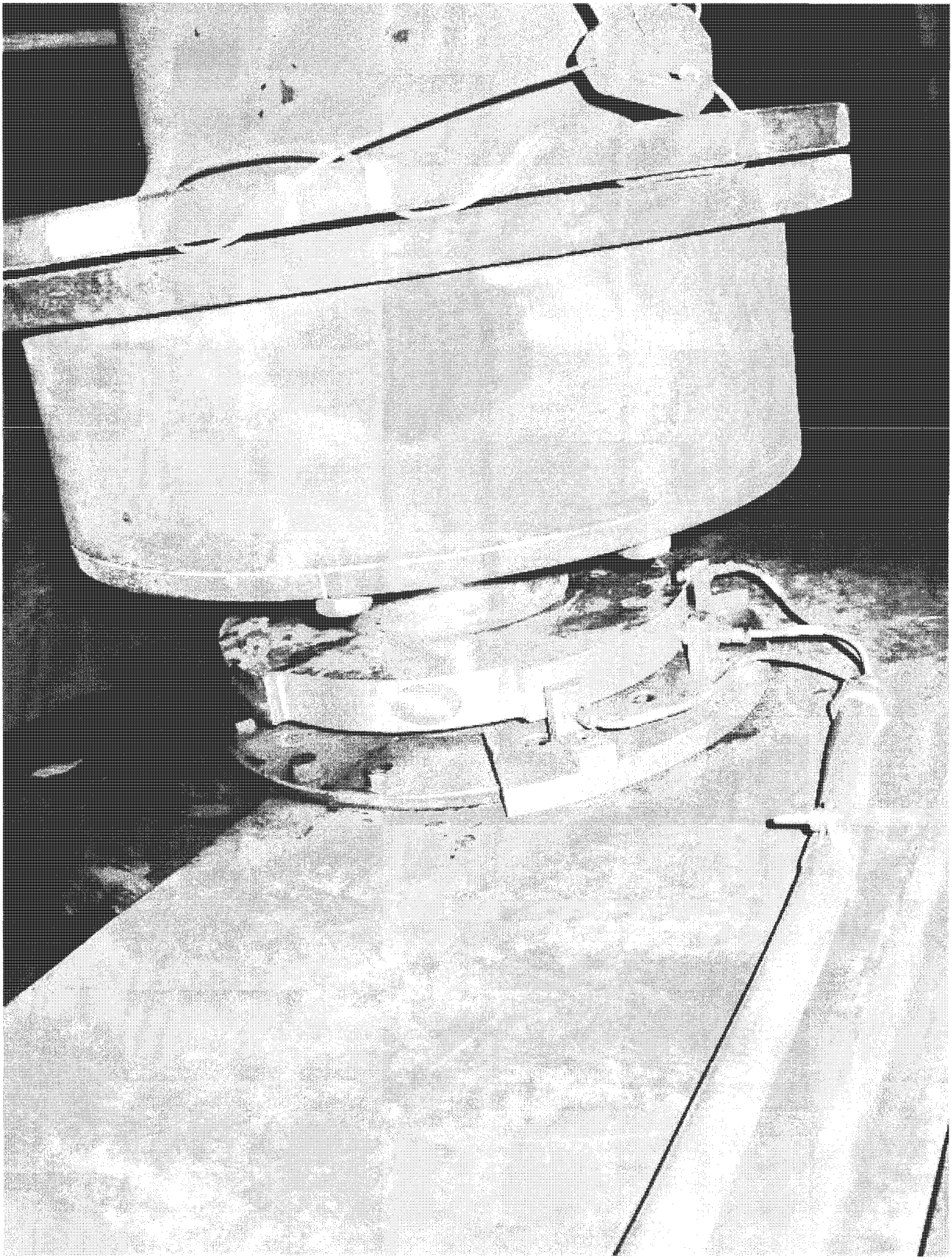

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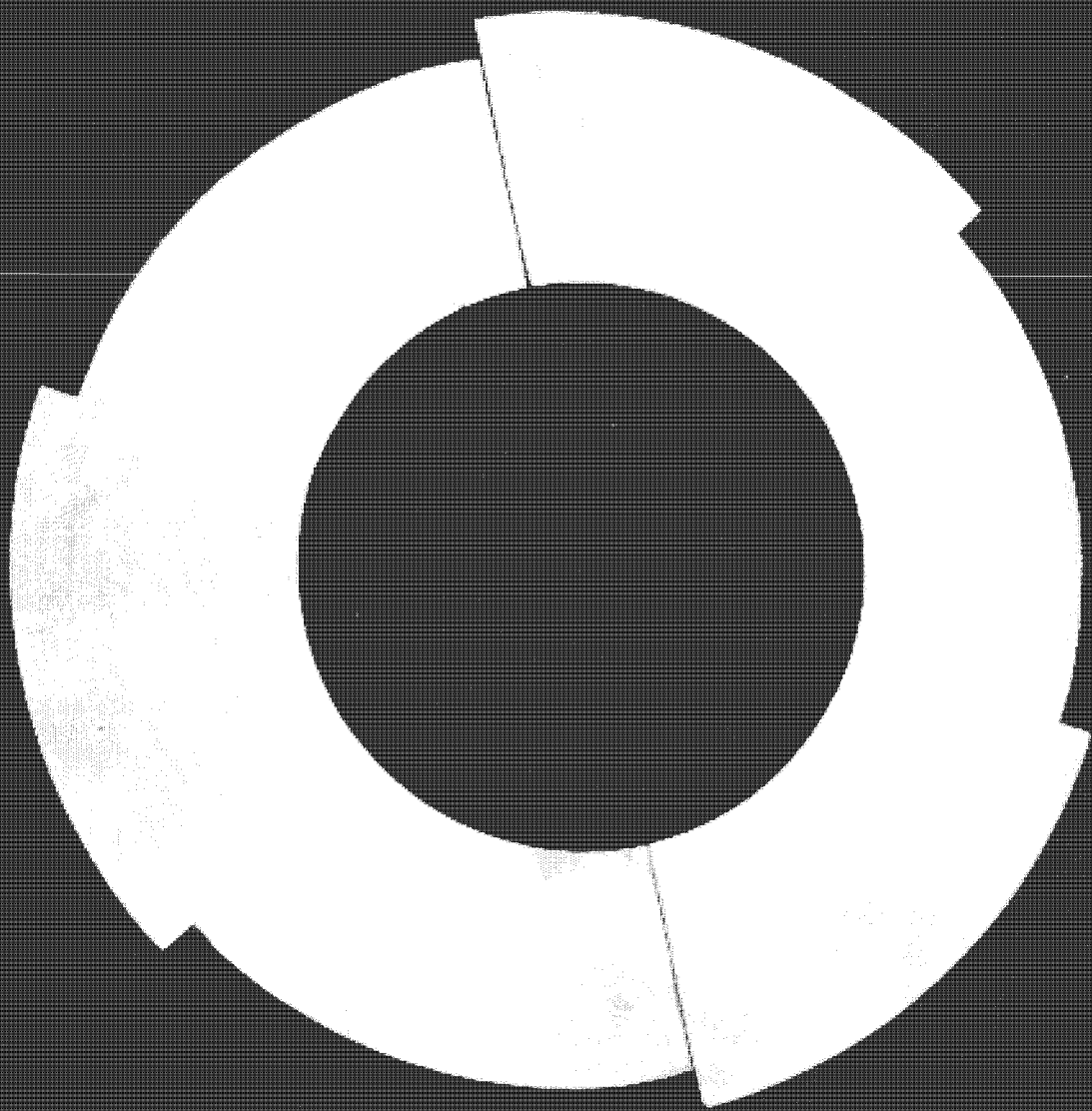

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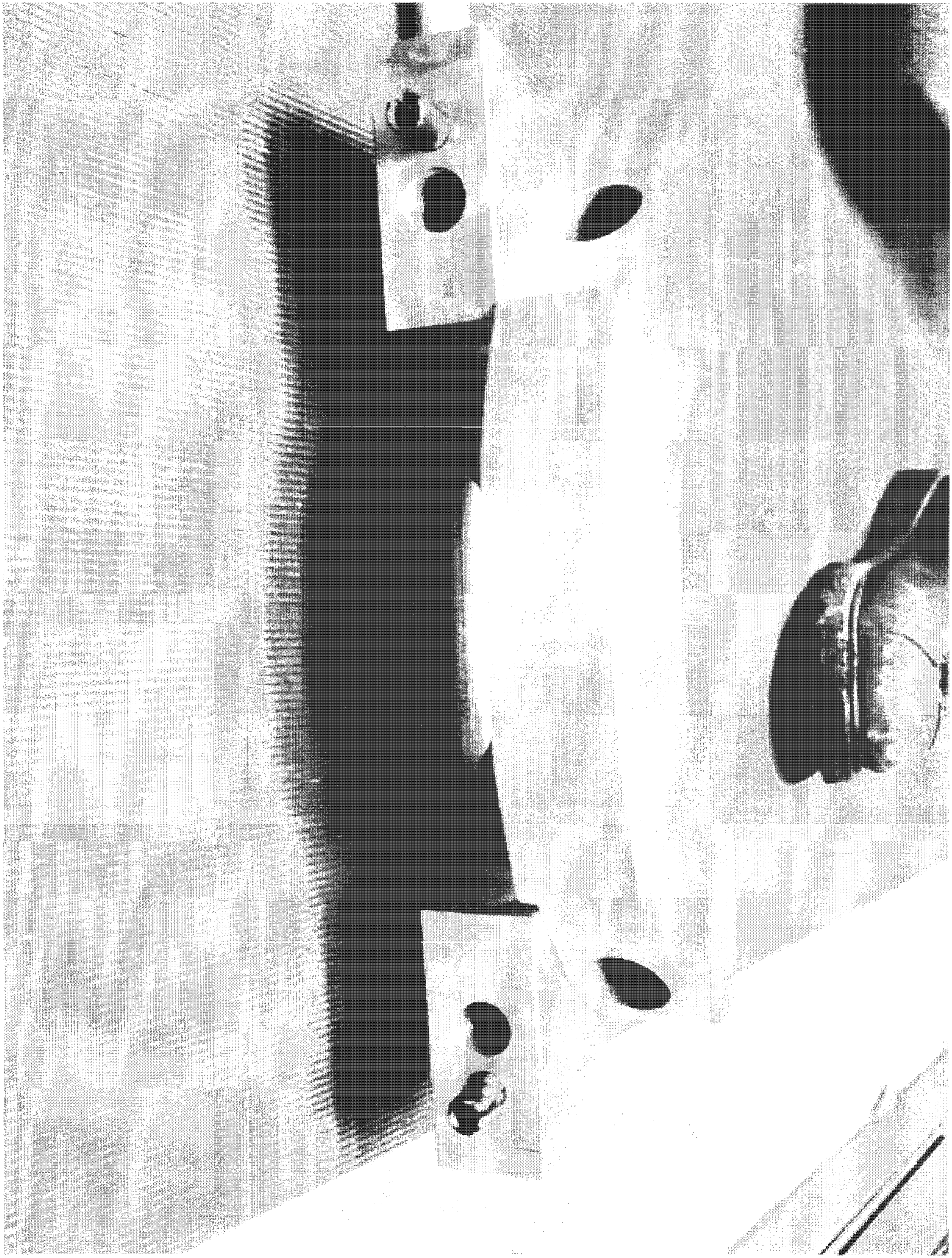

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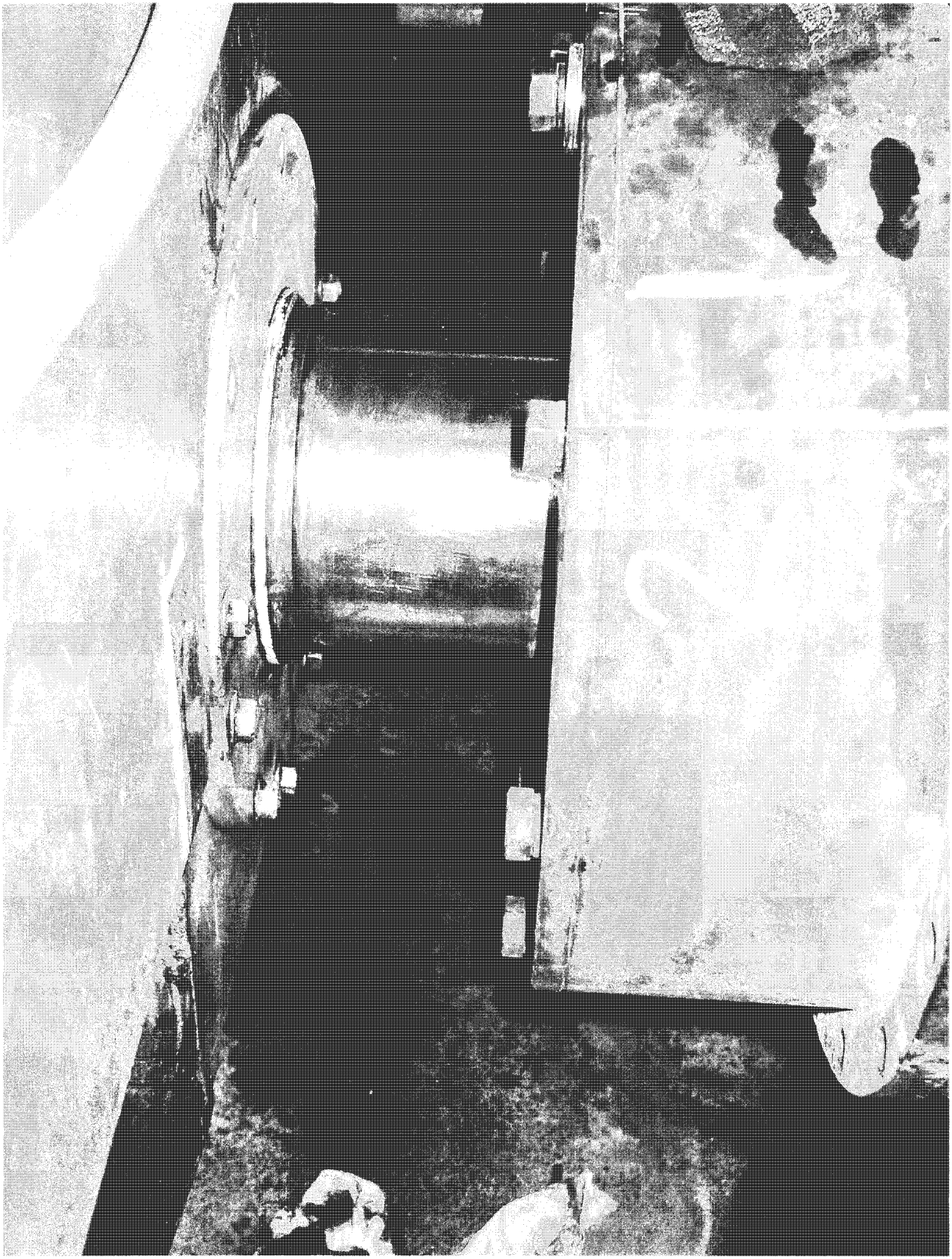

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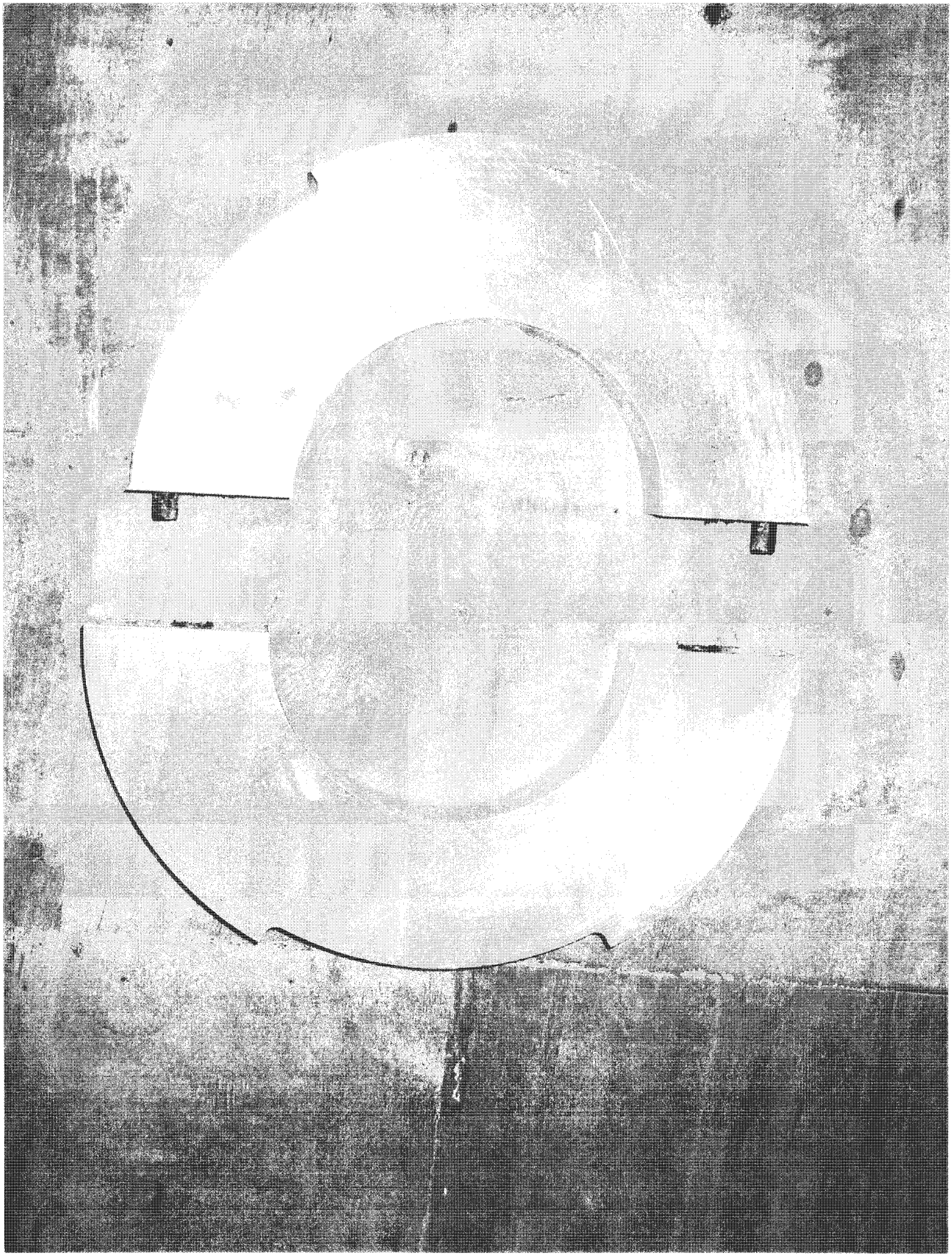

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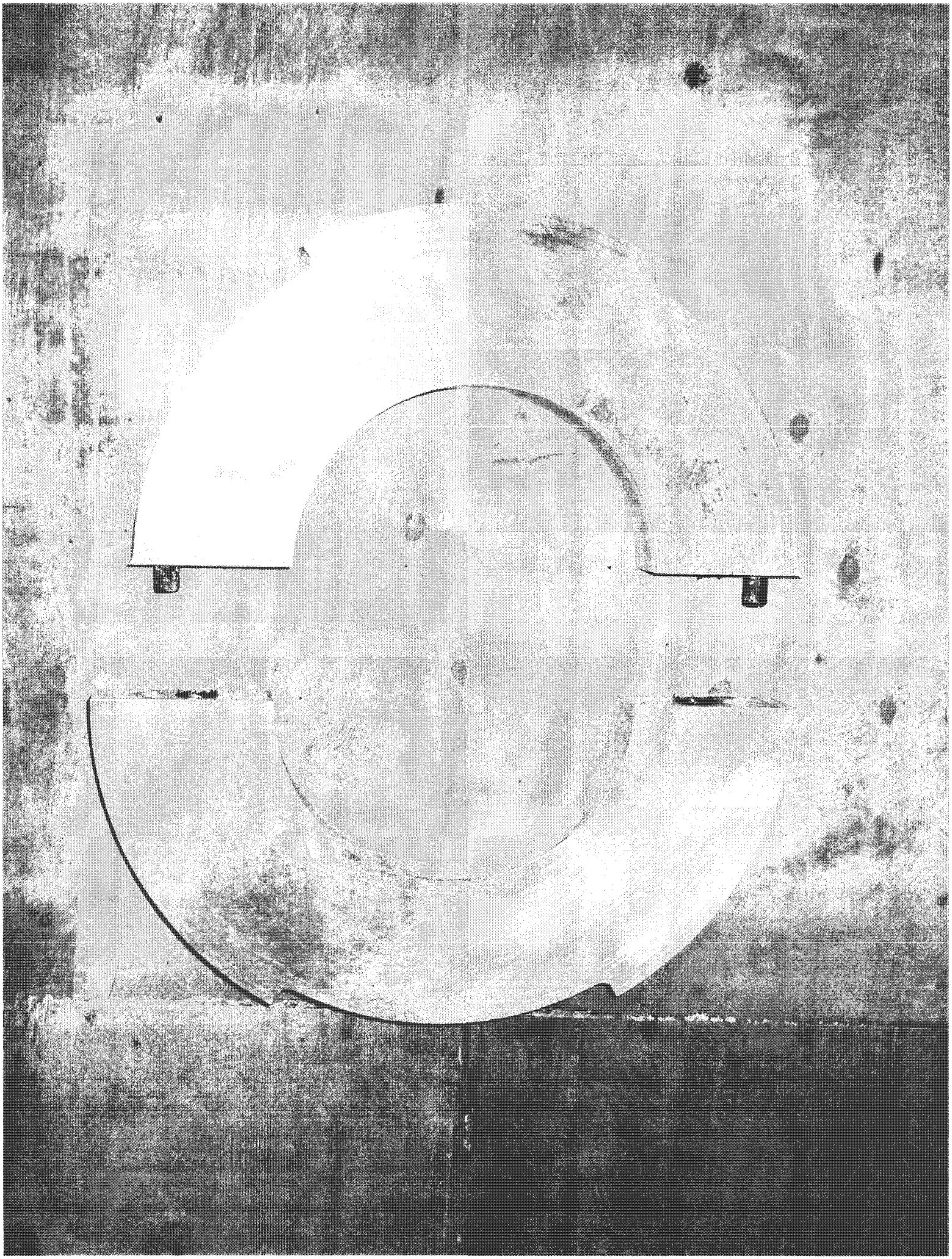

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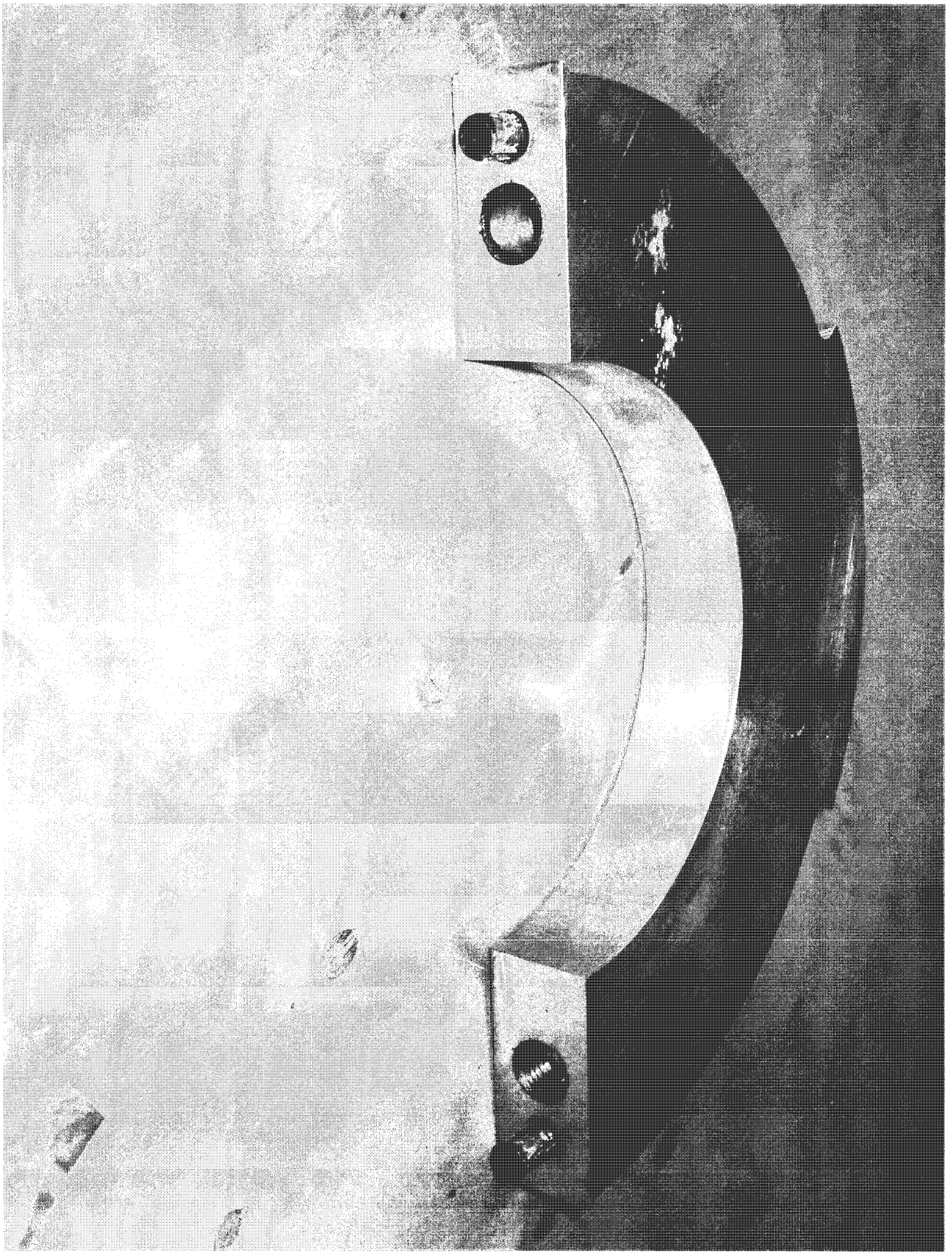

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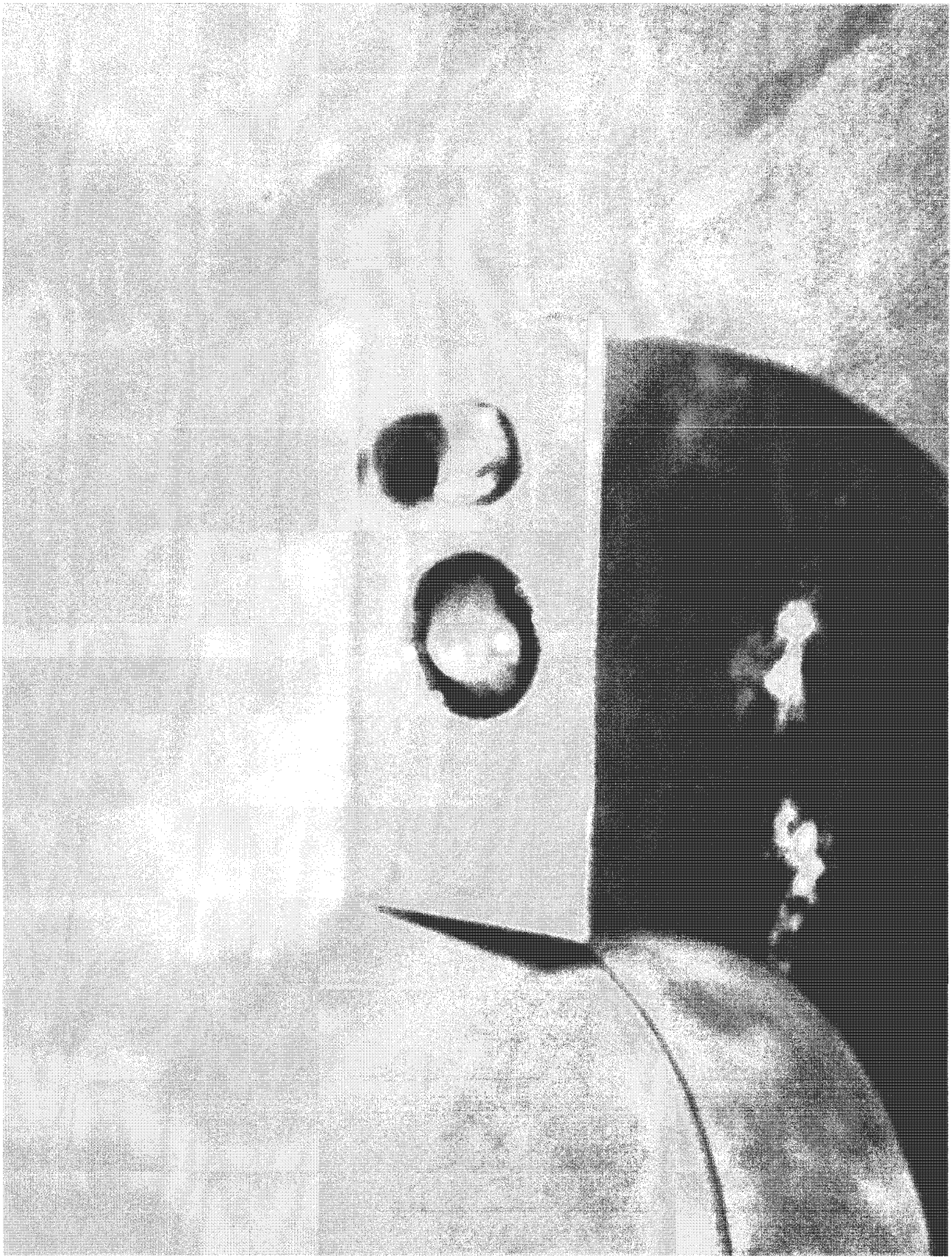

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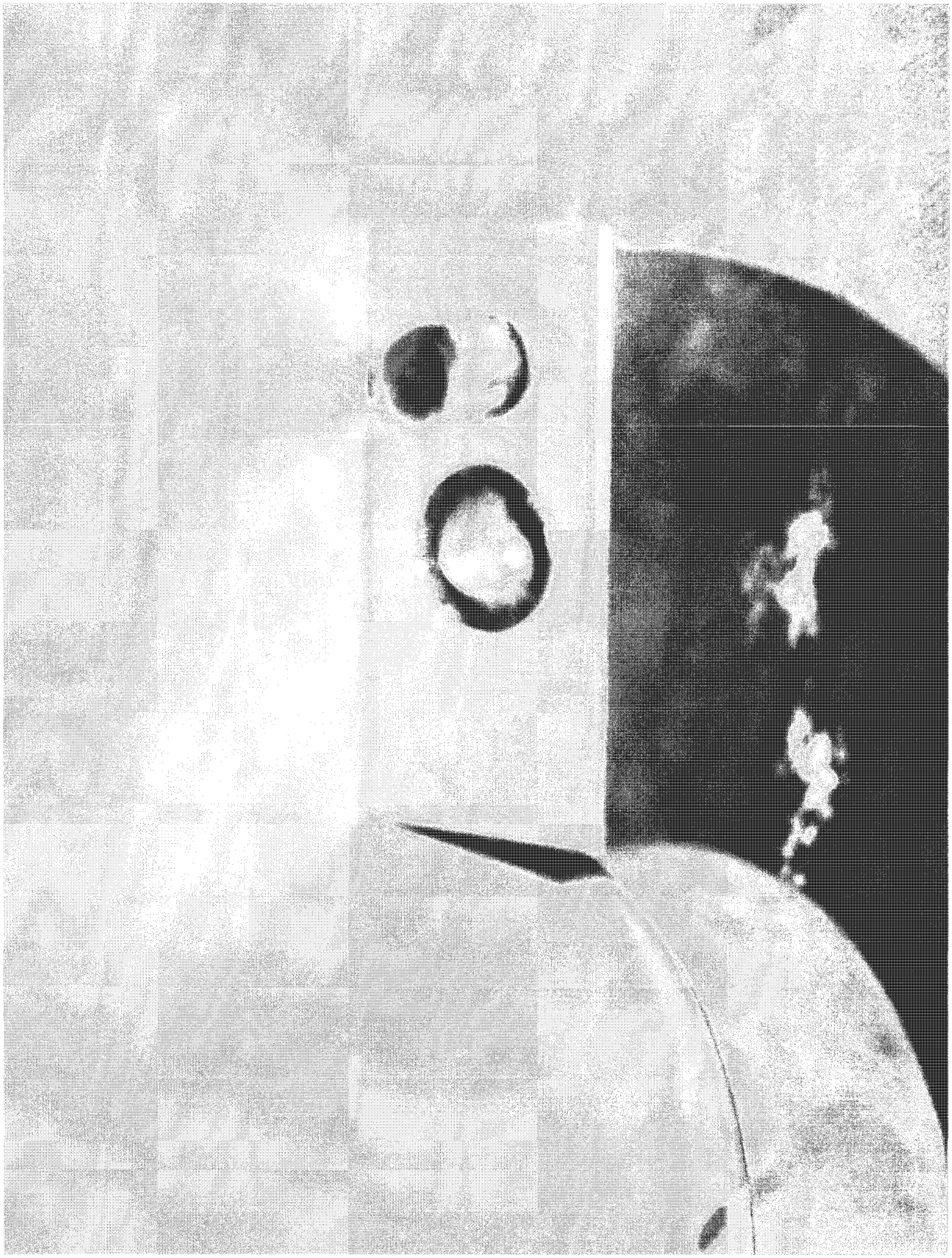

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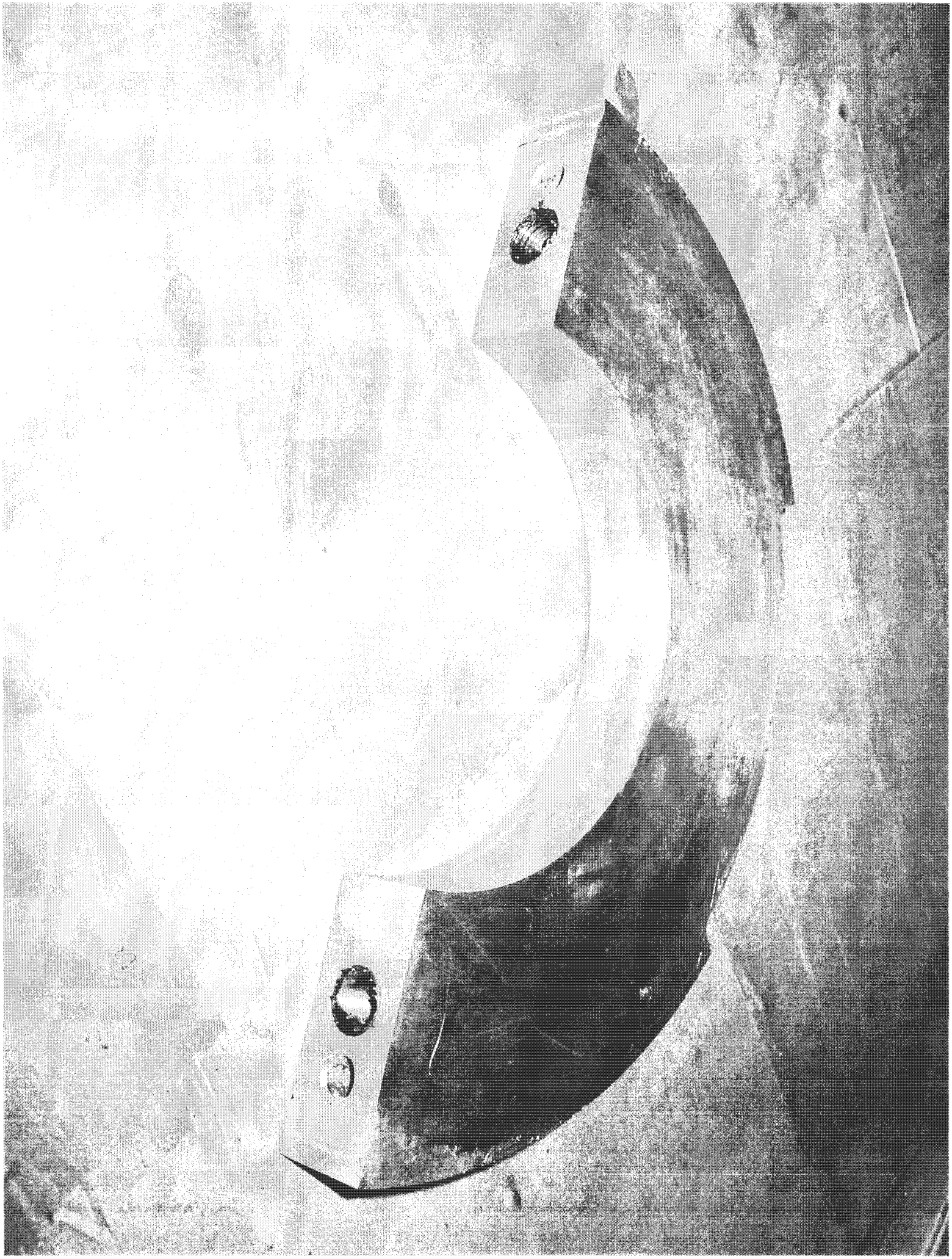

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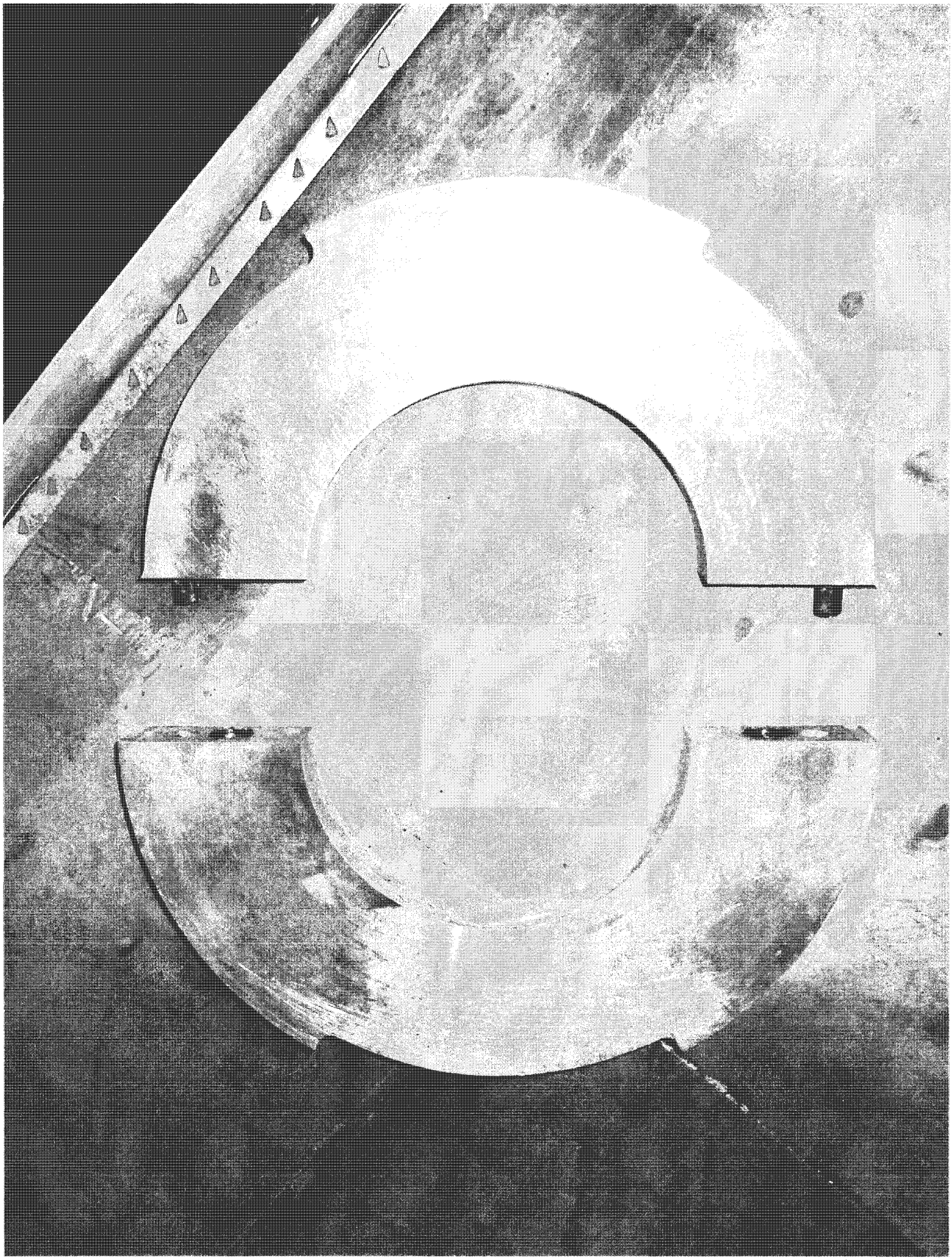

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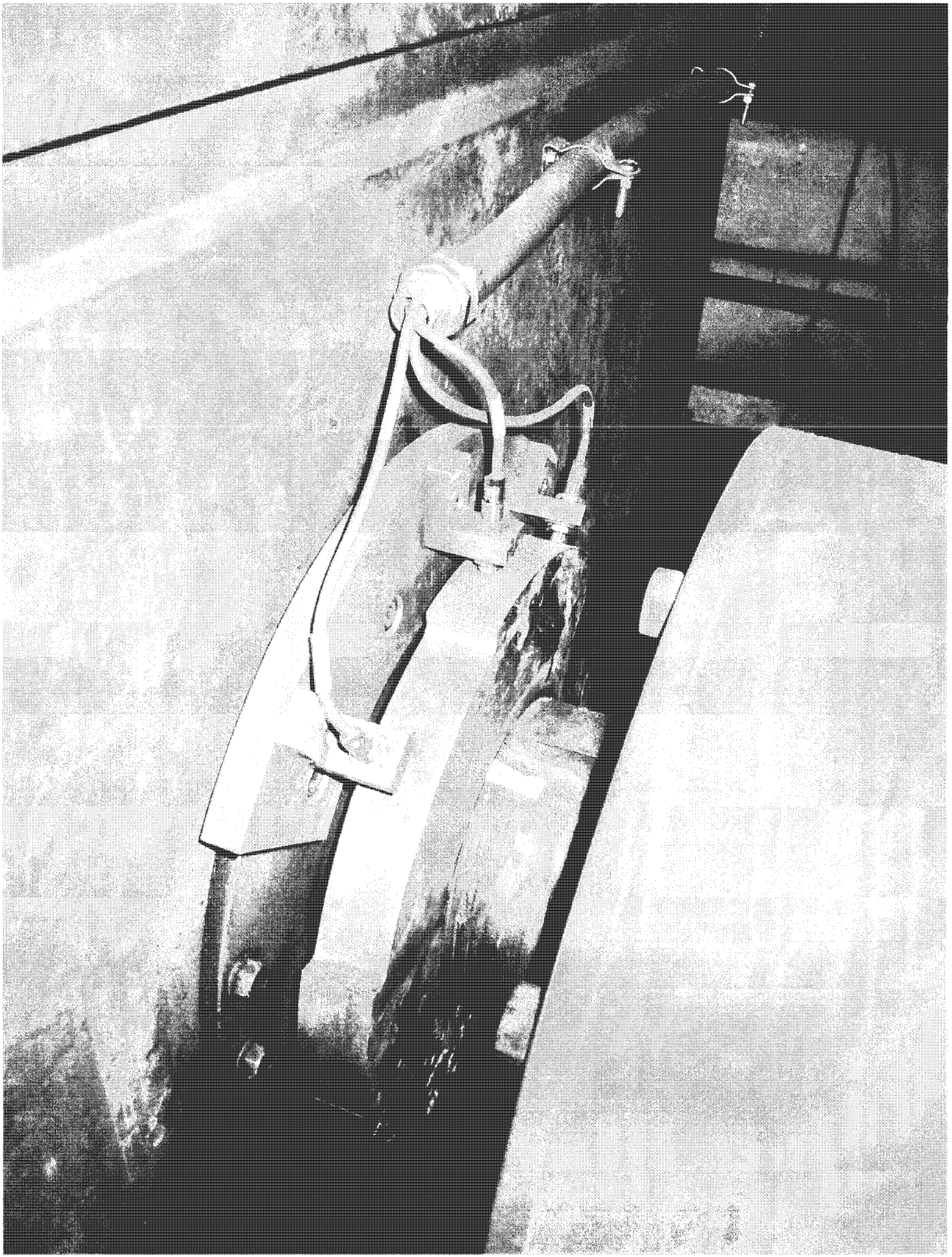

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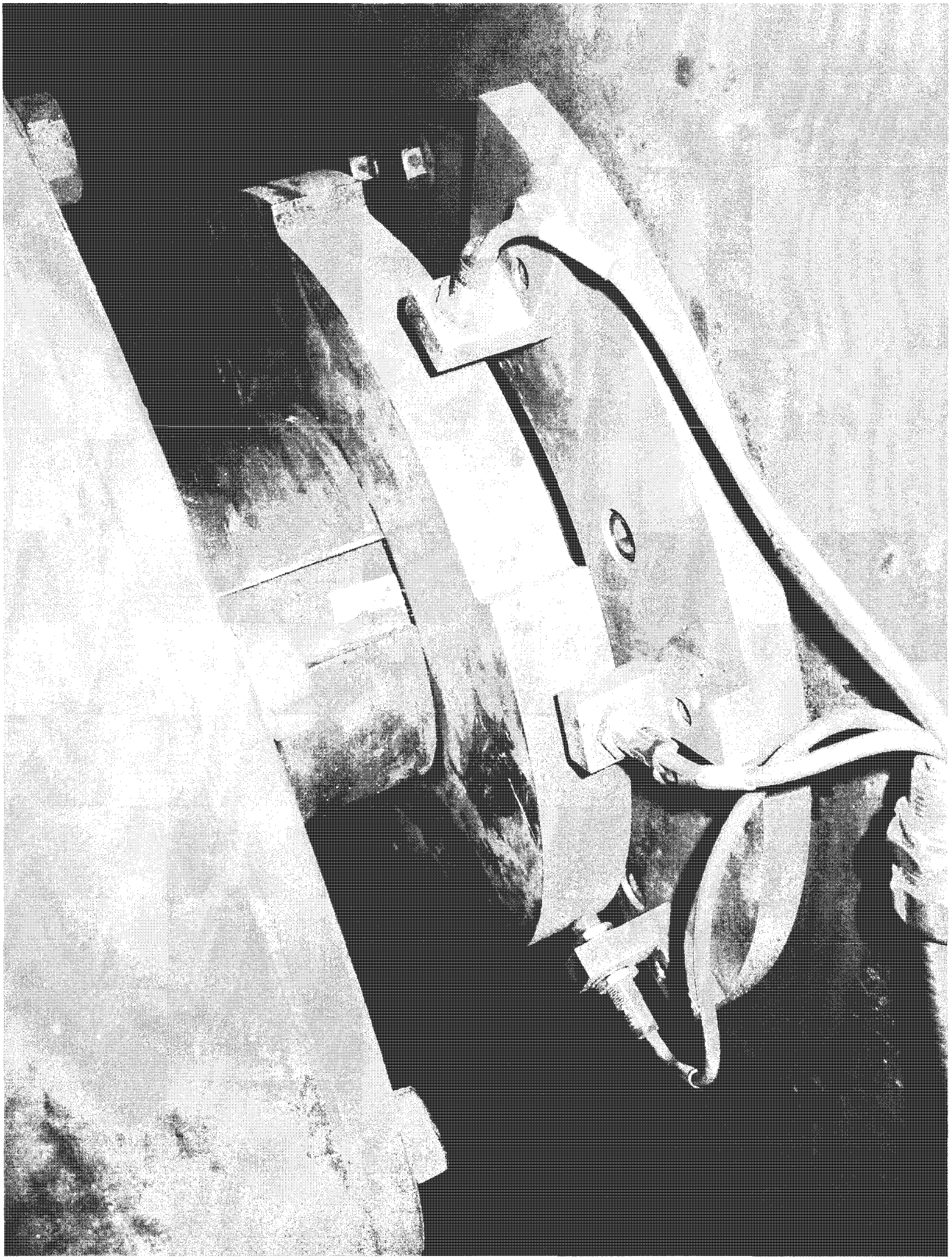

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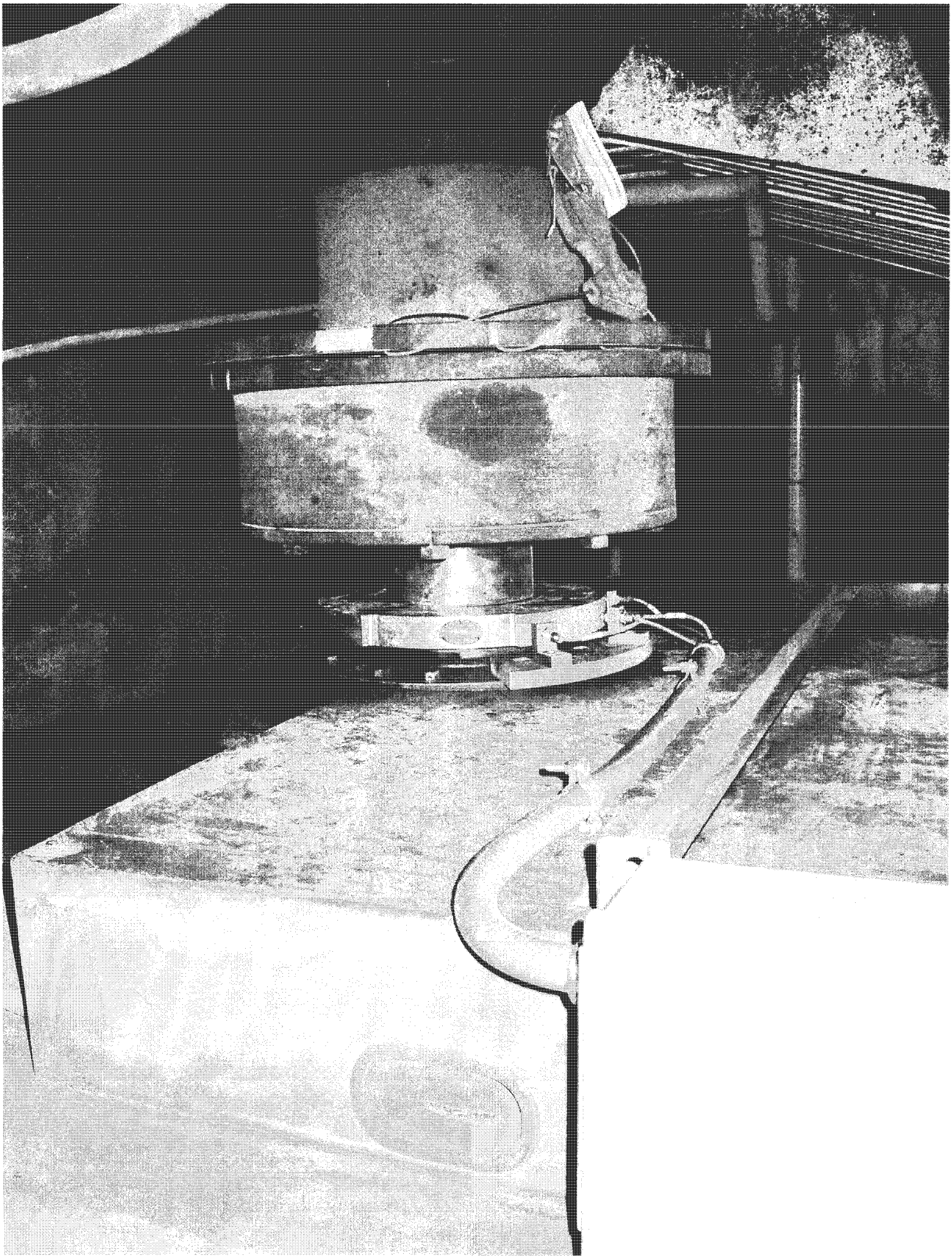

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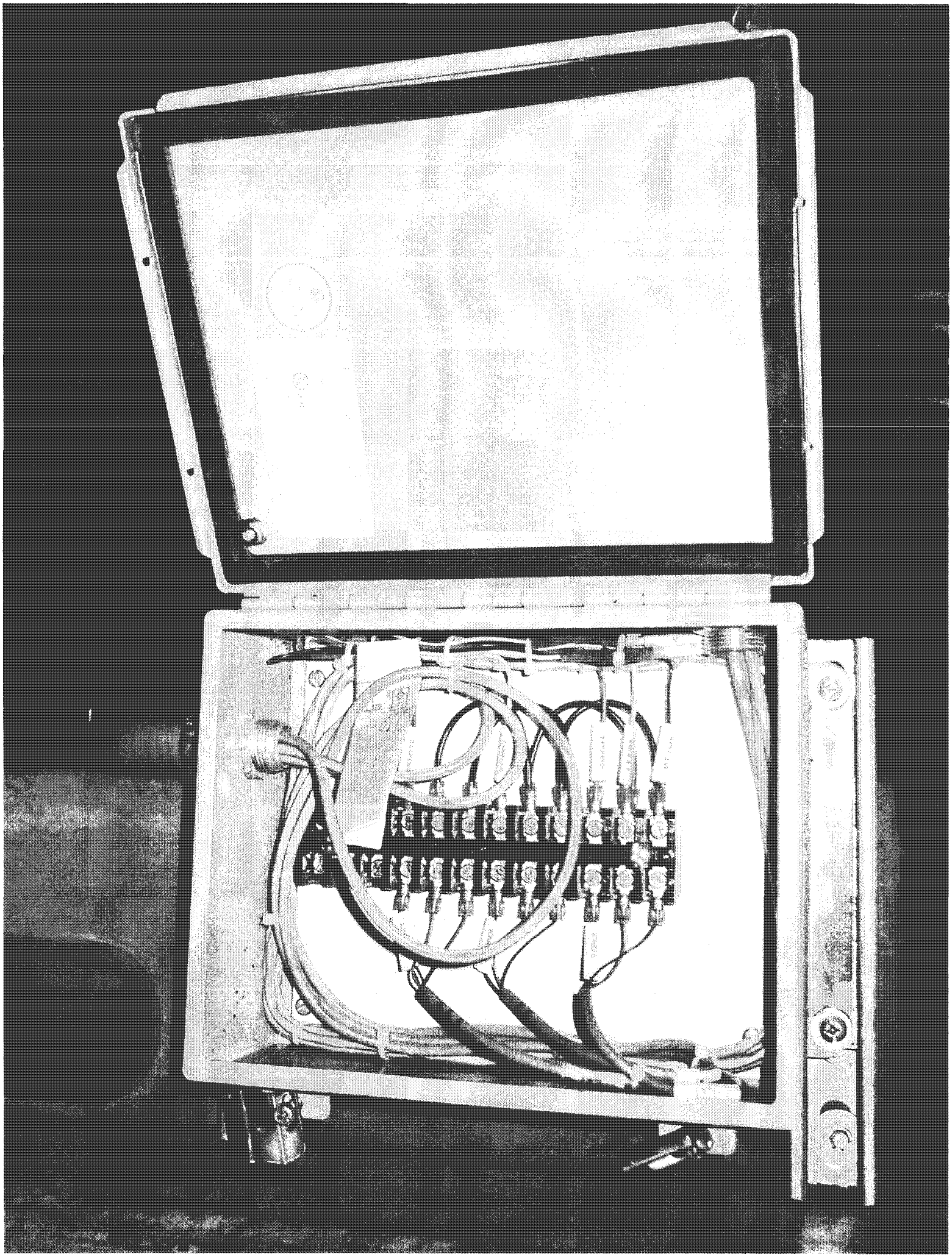

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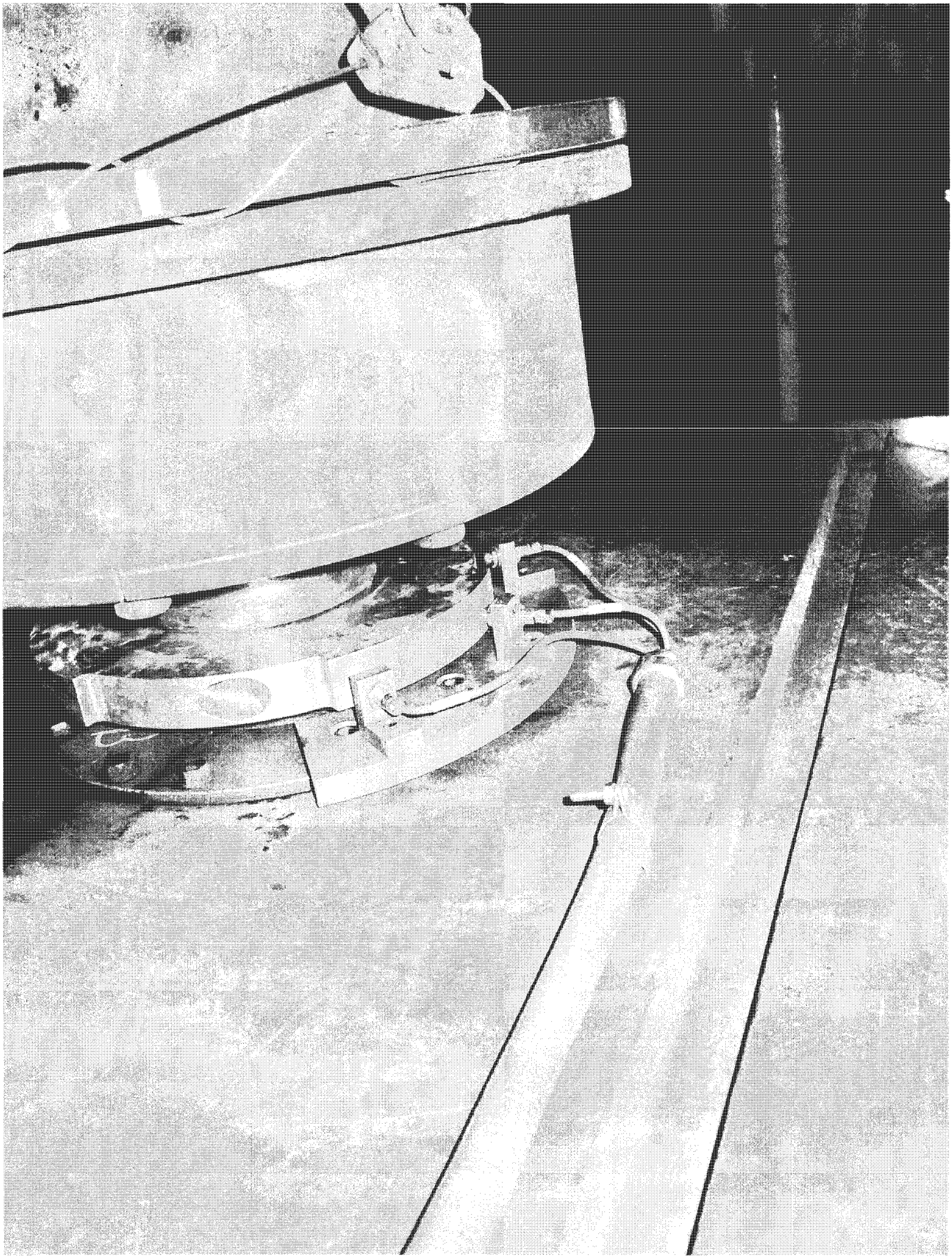

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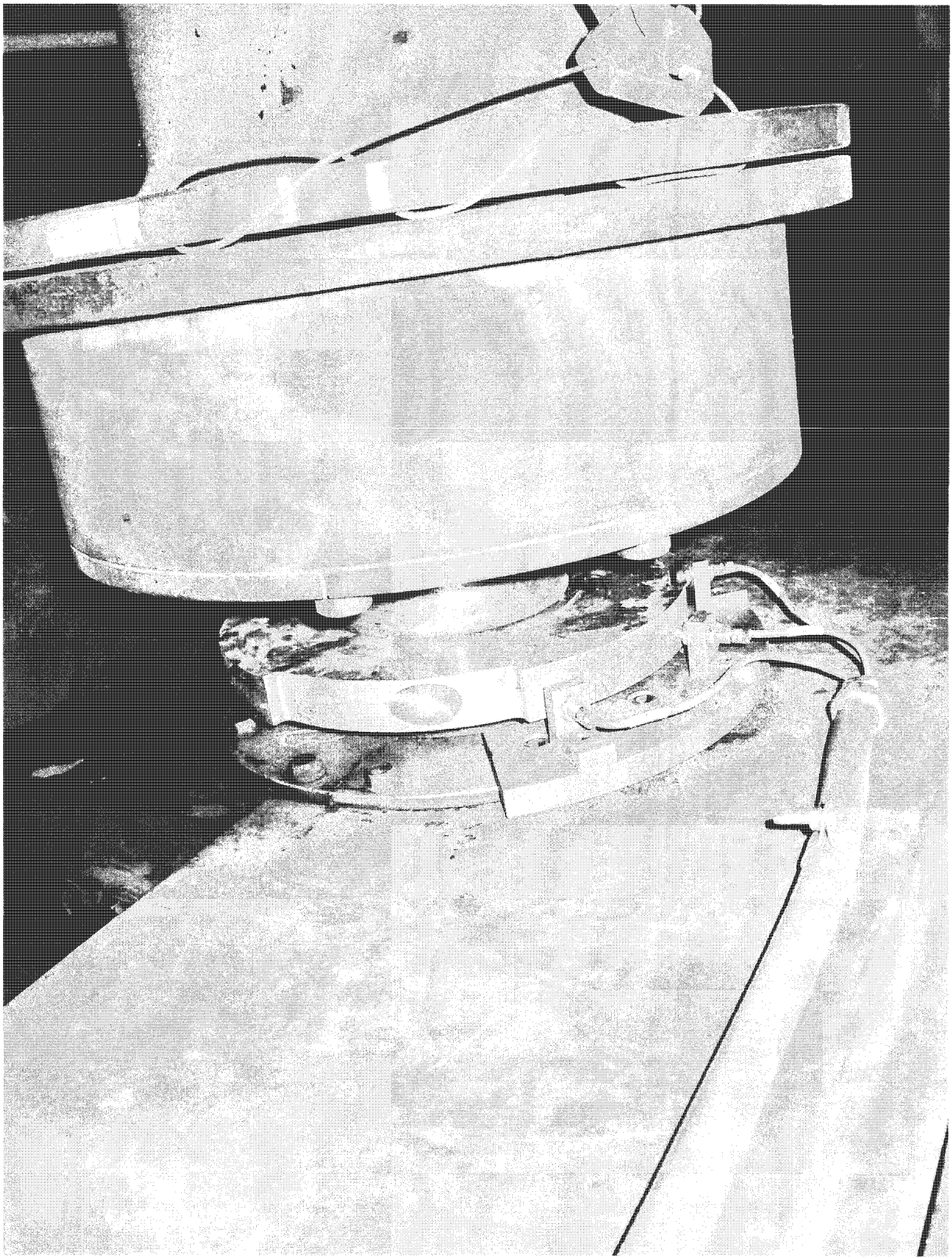

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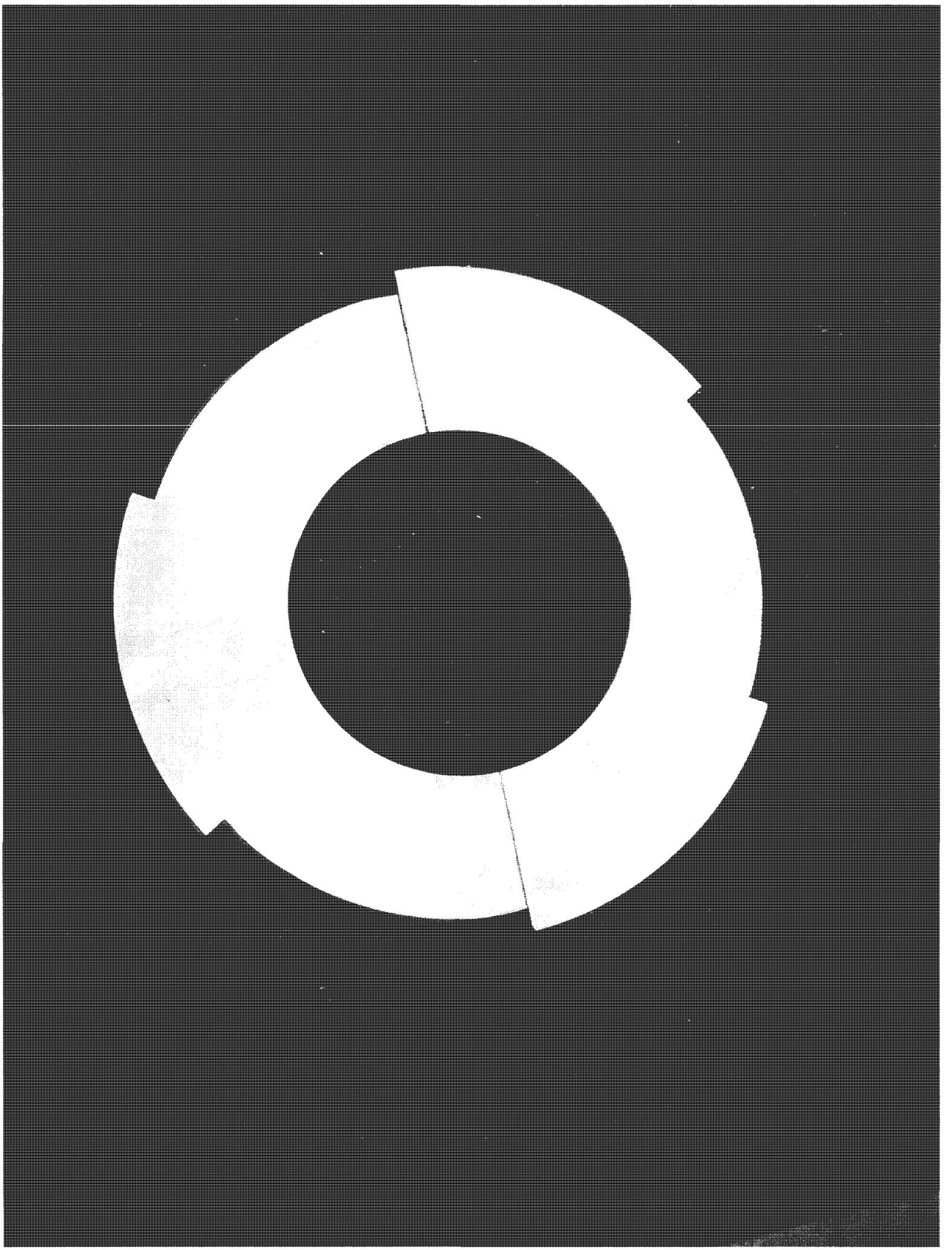

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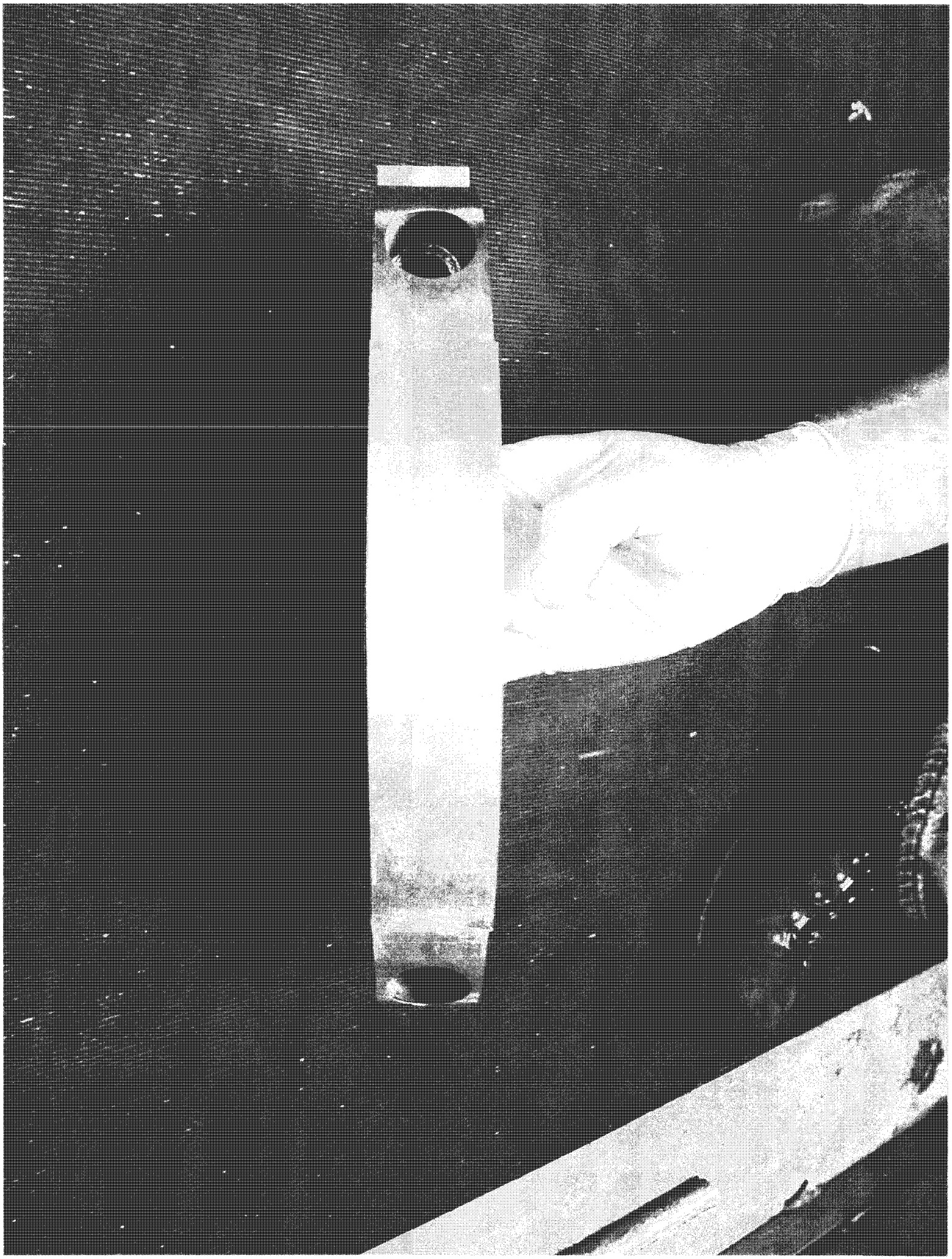

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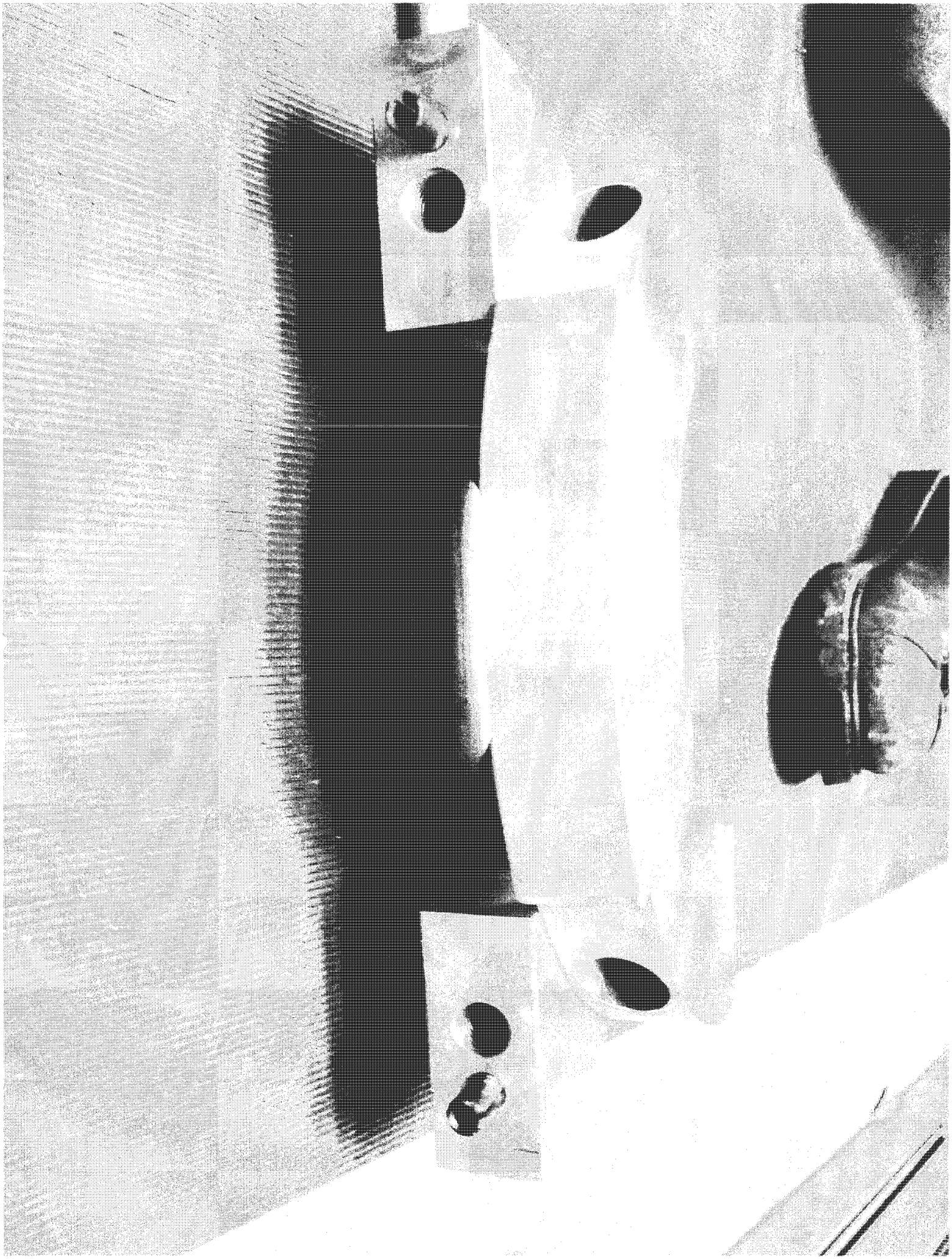

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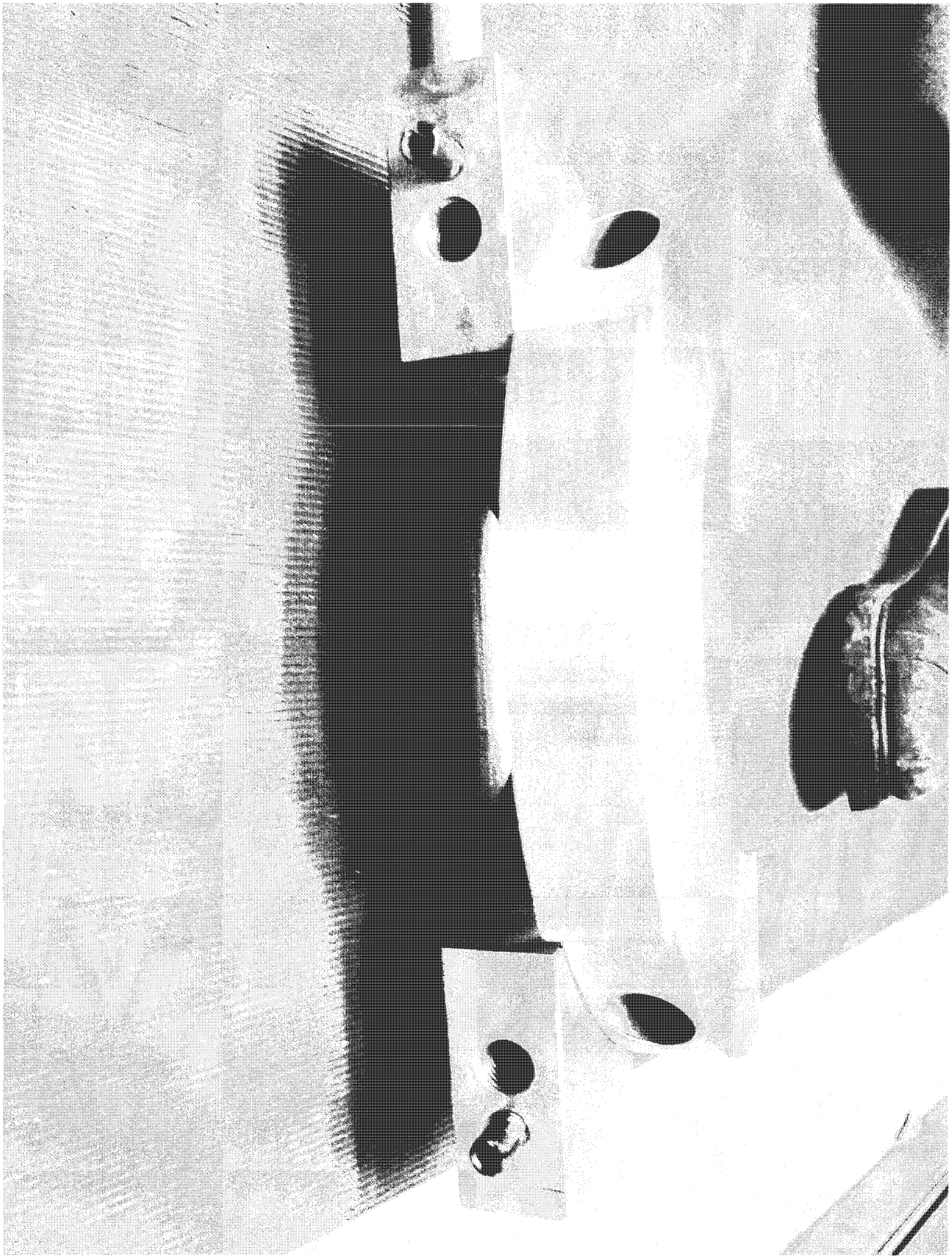

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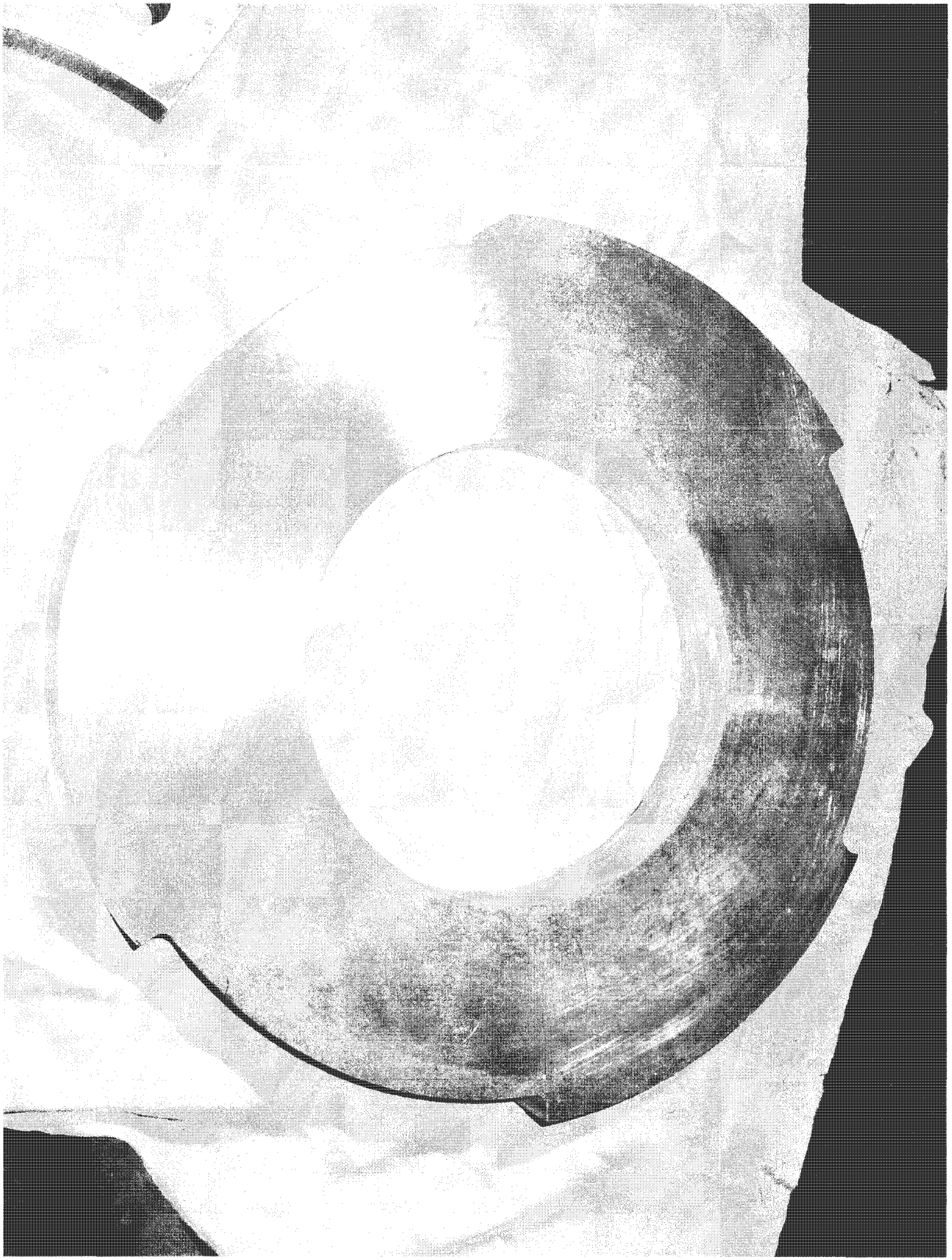

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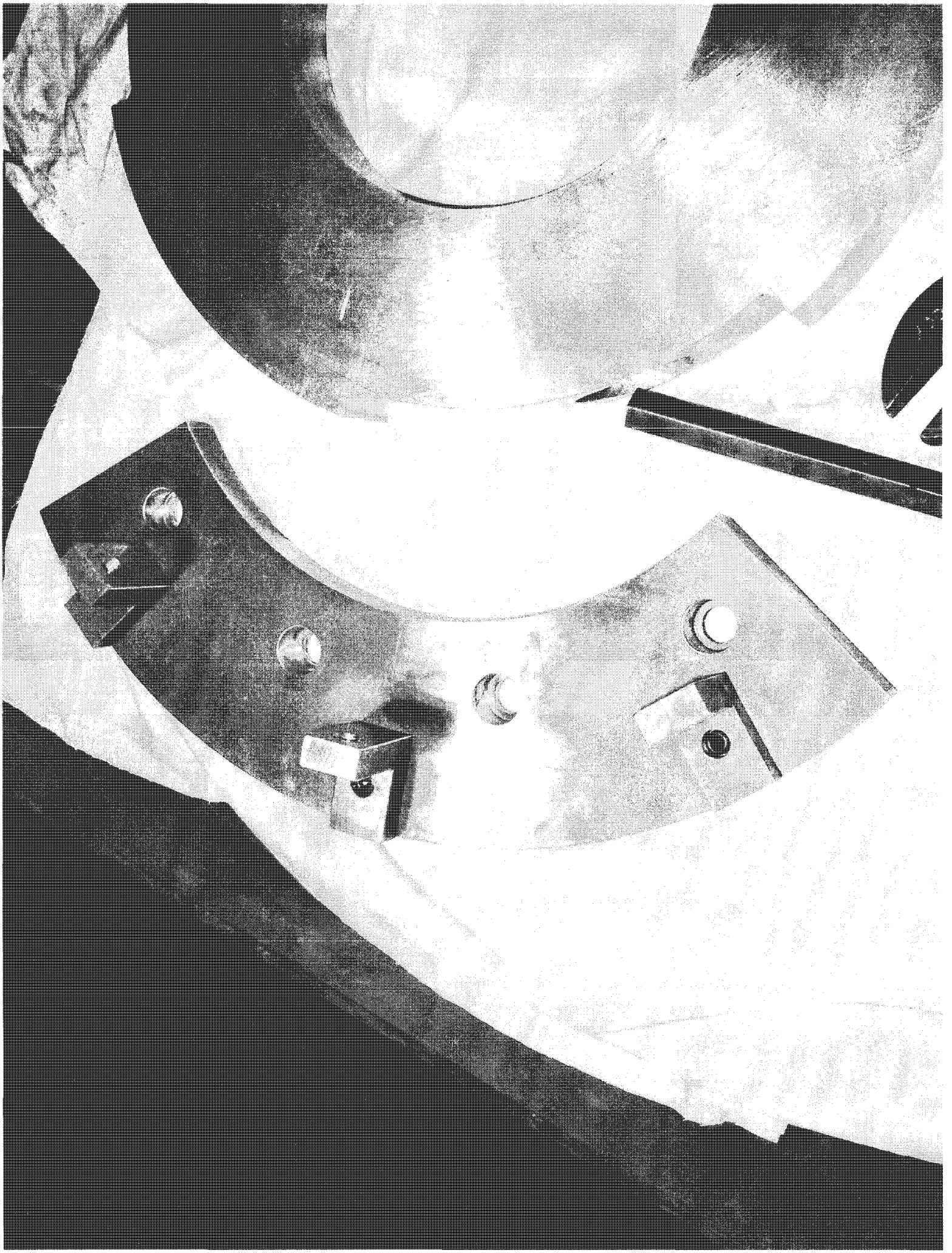

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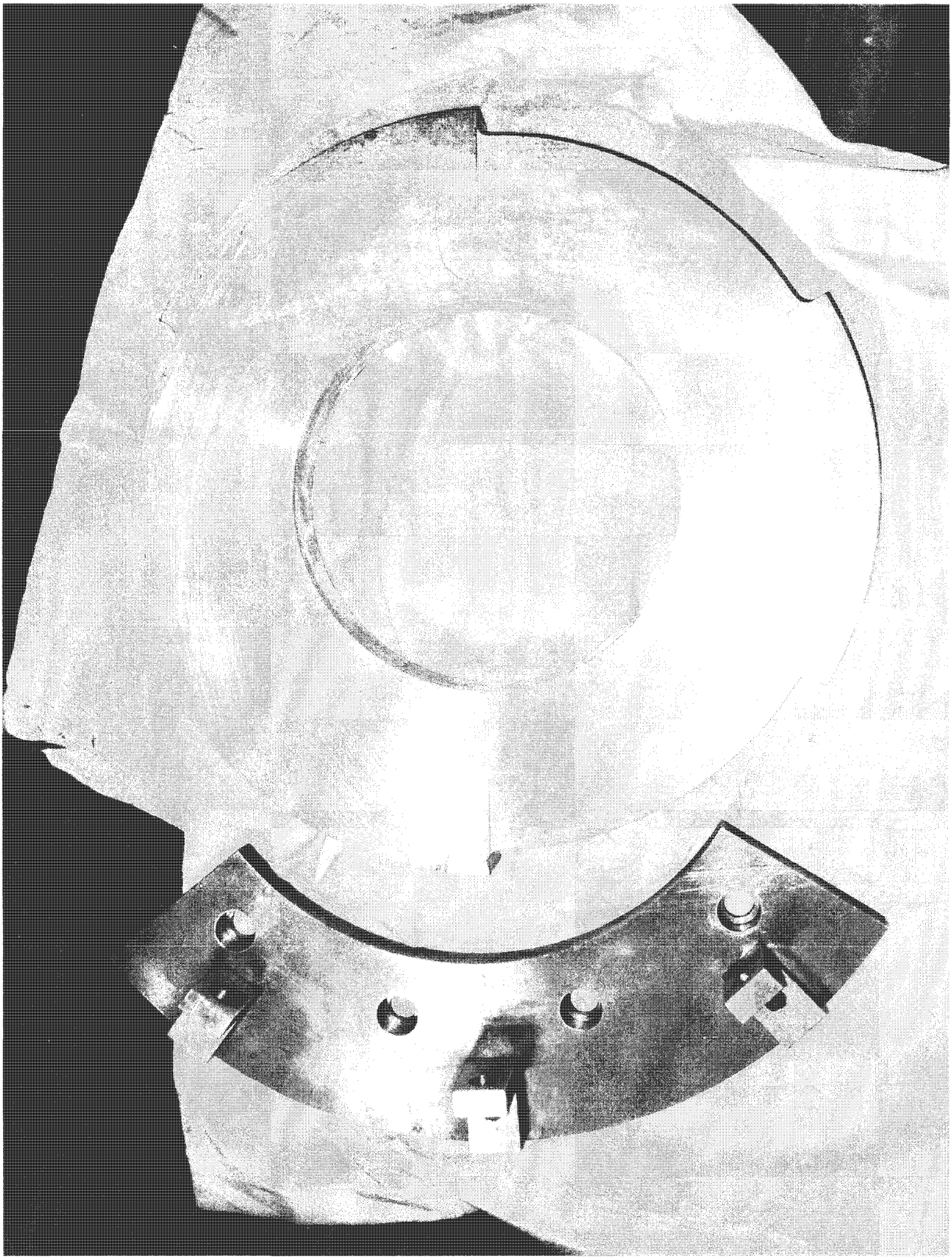

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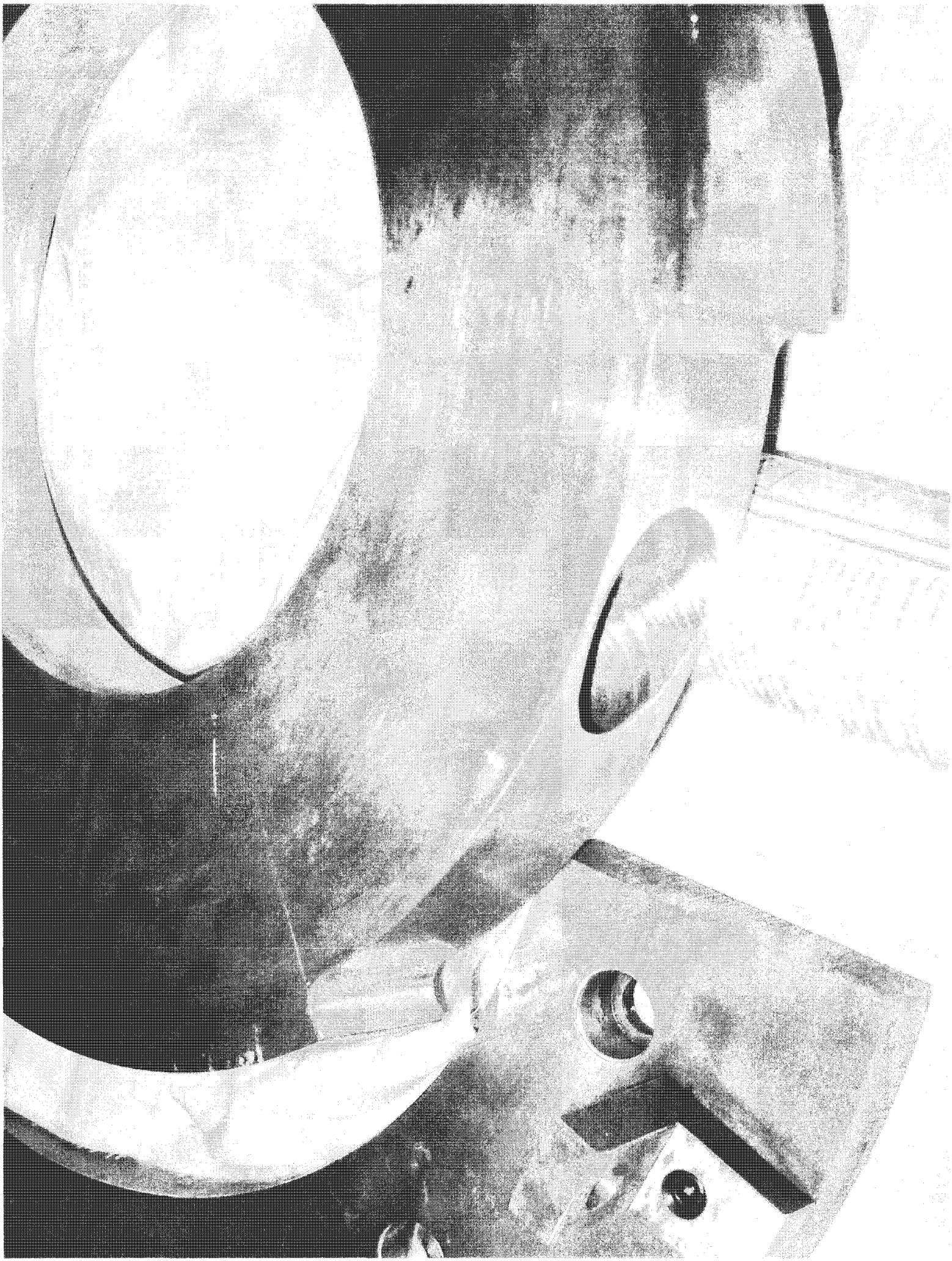


IP7014905

Shaft Encoders for SYNCDRIVES

For the Alstom Sigma based syncdrives it is necessary for the motor to be fitted with shaft position sensors. A description of the operation of the sensors and a recommendation for their placement is given below.

Function

The shaft encoders connect into the sigma digital I/O board using three (or six on dual wound single sigma systems) dedicated 24v digital inputs. These inputs are connected by the system firmware into the machine converter firing circuit. They are used during starting and low speed operation when the available back emf from the machine is insufficient to commutate the machine converter thyristors. Based on the pattern of received sensor feedback the firing circuit firmware determines which pair of machine bridge thyristors will conduct at any particular instant in time.

With the machine at standstill, the encoder pattern selects with thyristors and hence which phases of the stator will carry current. The direction of current flow is also selected. When the machine is turning the encoder determines when the stator current is transferred from one phase to another so that maximum torque is maintained at all times.
Once a certain speed is reached (normally around 10-12%) the machine can produce enough back emf to naturally comutate the thyristors, the encoders are then only used as a supplemental source of speed feedback.

Mechanical Arrangement

The encoder arrangement varies with machine pole number. There is always one rotor lobe per pair of motor poles and the rotor lobes always cover an arc of 180° electrical.

There are 3 or 6 inductive proximity sensors separated by an angle of 120° electrical. Each sensor produces an output voltage while sensing the presence of a rotor lobe. When the motor is turning at constant speed, each sensor produces a nominally square wave output voltage. In the case of six phase or dual wound machines, the second set of encoders have the same 120 degree electrical separation but are displaced 30 electrical degrees lagging the first set.

Provision should be made for angular adjustment of all three or six sensors simultaneously, by mounting them on a common slotted ring bolted to the machine housing. The slot range of adjustment should cover a 120° electrical arc. The mechanical arrangement should allow angular adjustment to be done without disturbing the air gap settings.

Initial Sensor Alignment

Check that the sensors are positioned so that with the motor shaft at its magnetic center, the sensor tips are at the axial center of the rotor lobes. The axial width of the rotor lobes should be such that no part of the sensor tip ever extends beyond the lobe surface at the limits of shaft end play.

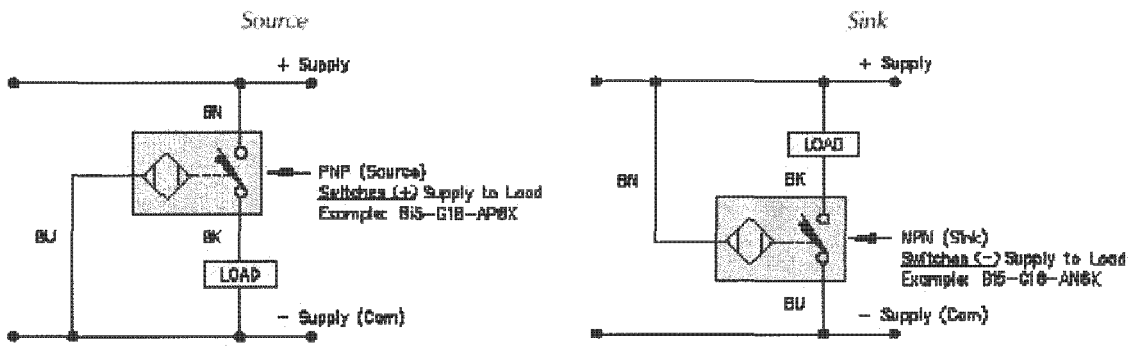
Check that the sensor bodies fan out radially from the shaft center and that they are also perpendicular to the shaft axis. The object is to ensure that the sensor tip is essentially parallel to the surface of the rotor lobe.

Sensor Air Gap Setting

Generally, the air gap between the sensor tip and rotor lobe surface should be set to 0.047 ± 0.004 inches. (1.2 ± 0.1mm) With this gap setting the sensor should switch to the on state when the edge of the rotor lobe just covers half the sensor tip.

DC power supply requirements for sensor testing

A suggested method of connection for the three wire Turck and or Pepperl & Fuchs type of encoders is shown below. The load can consist of a 10K ohm resistor.



Electrical Check of Encoder Operation

Having first set the sensor air gaps, the motor should be turned to check that all three sensors produce an output voltage across their load resistors. When a lobe is sensed, the output voltage should be 24v (or whatever V supply is used) In the absence of a lobe, the output voltage should be less than +1 volt. Check that each sensor changes state when approximately half the sensor tip is covered by a lobe.

If the motor can not be turned, a suitably shaped ferrous metal object can be used in place of the lobe (e.g., a screwdriver).

Setting of Encoder Phasing

It is suggested that the motor be run as an unloaded generator at some convenient low speed and that a comparison be made between the phasing of the induced stator voltages and the sensor signals.

First determine the specified direction of rotation for the motor and check electrically that the phase sequence of the induced stator voltages is 1,2,3 (or A,B,C) as marked on the stator cables/terminals. Also verify which motor winding is leading (in the case of a dual wound motor).

Permanently label each sensor and it's leads 1,2,3 (or Delta1, Delta2, Delta3, Wye1, Wye2, Wye3 in the case of a six phase machine) in the order in which the sensors come up as determined by the specified direction of shaft rotation. Sensor 2 will always be the middle sensor in the group. It must be noted that the leading winding is associated with the first set of encoders and the lagging winding with the second set of encoders.

With the encoders set up as shown in the above diagram, connect a single phase suitably rated potential transformer (with the secondary winding having the same polarity as the primary, as indicated by the dots on the windings) to the stator windings of the machine.
Adjust the angular position of the encoder mounting ring so that the phase relationship between the rising edge of the encoder signal and the positive going zero crossing of the stator voltage waveform conform with the following table.

1. Encoder 1 positive rising edge is in phase with the positive going zero crossing of stator phases 1-2
2. Encoder 2 positive rising edge is in phase with the positive going zero crossing of stator phases 2-3
3. Encoder 3 positive rising edge is in phase with the positive going zero crossing of stator phases 3-1

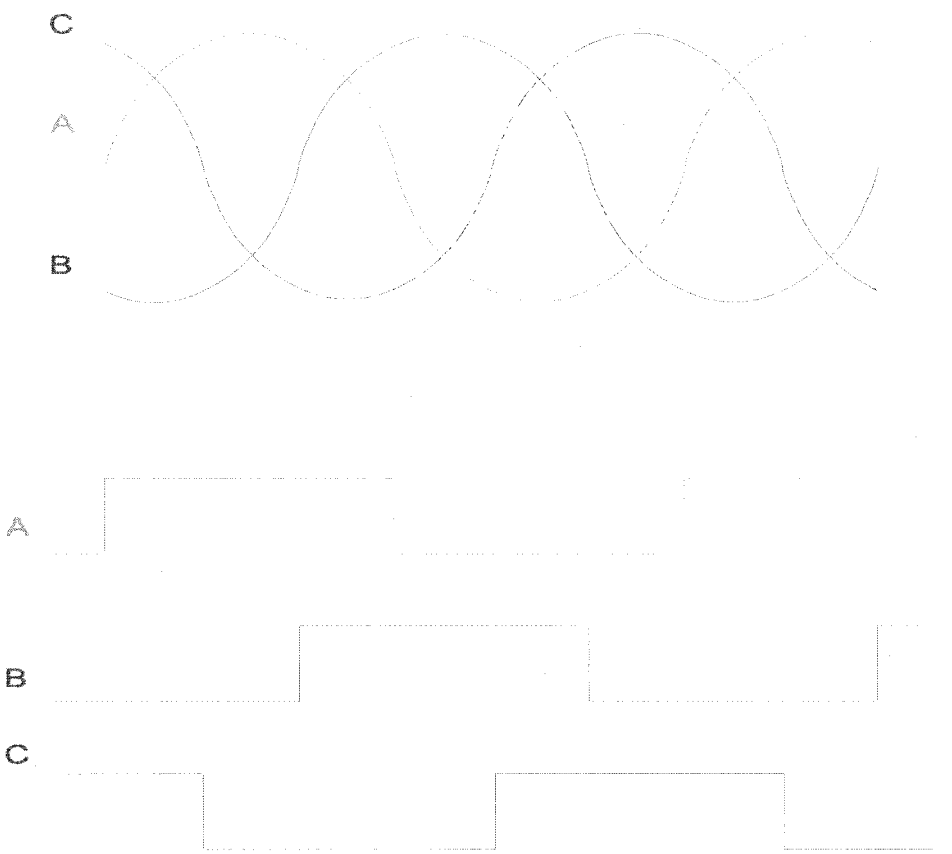
For a six phase machine, each set of encoders (Delta and Wye) must be aligned with the positive going zero crossing of the stator voltage waveform for that particular winding. After this test has been completed, there should be three or six encoders that are aligned with the three or six individual stator voltage zero crossings. Again ensure the probes are clearly identified.

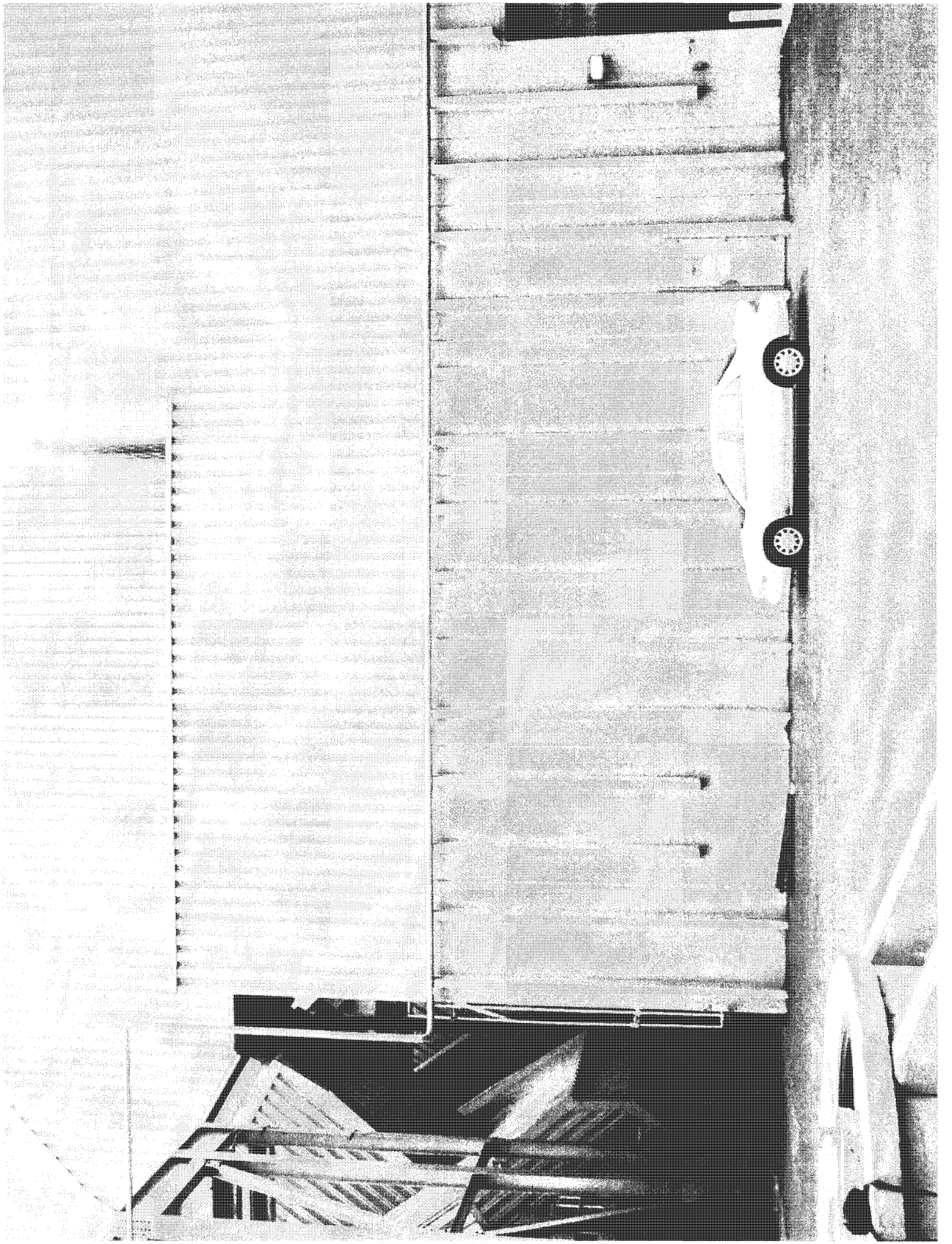
The mark space ratio of the encoder signal should be 50%. If the mark space ratio is not equal then the airgap of the individual sensors should be adjusted to achieve this.

Final check out

Once the above tests have been successfully completed, clearly mark the correct position of the encoder mounting ring with reference to the frame of the machine. Ensure all mechanical fastenings are secure and that the probe terminations are clearly identified at the external termination box.

Stator voltage waveform with respect to encoder signals





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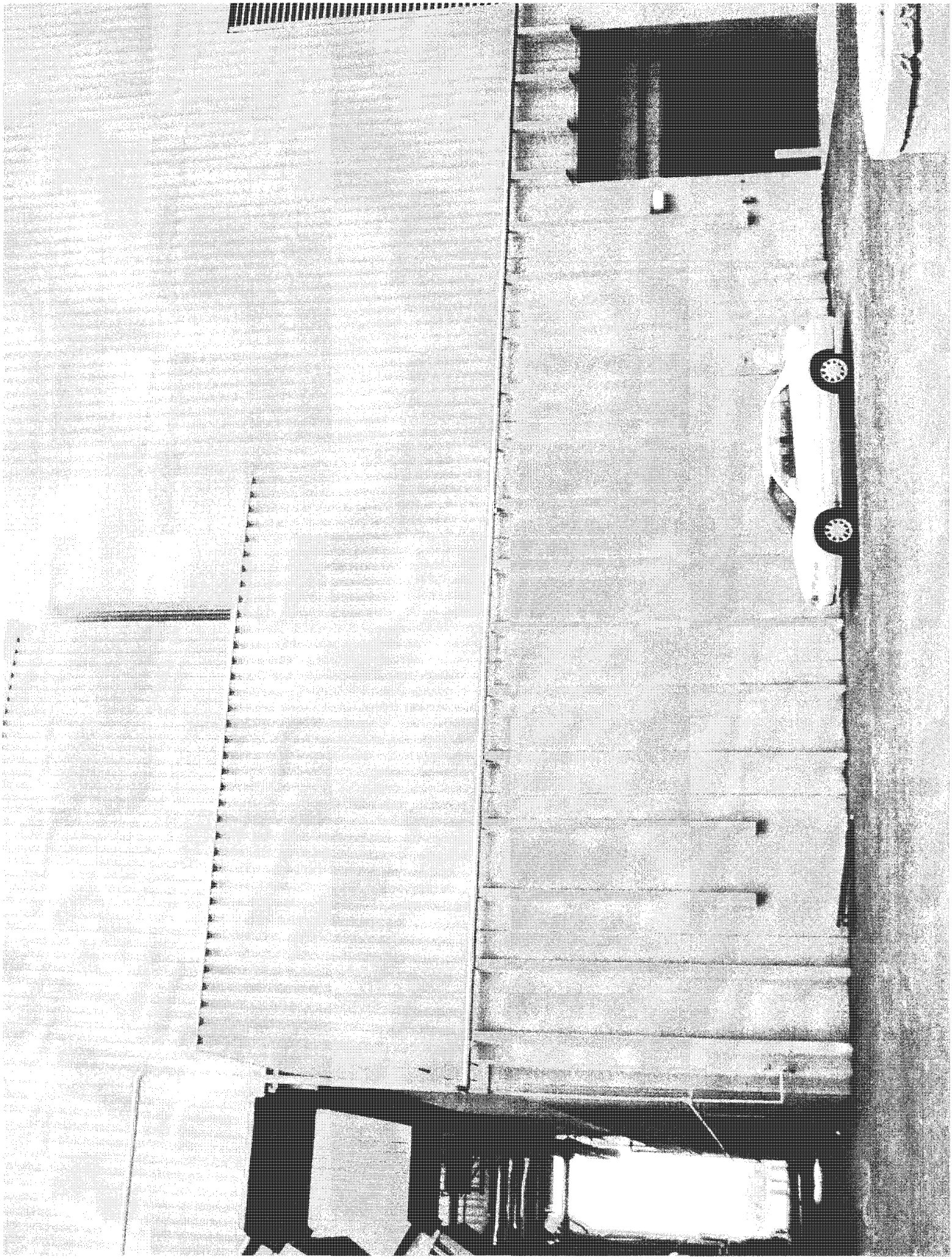

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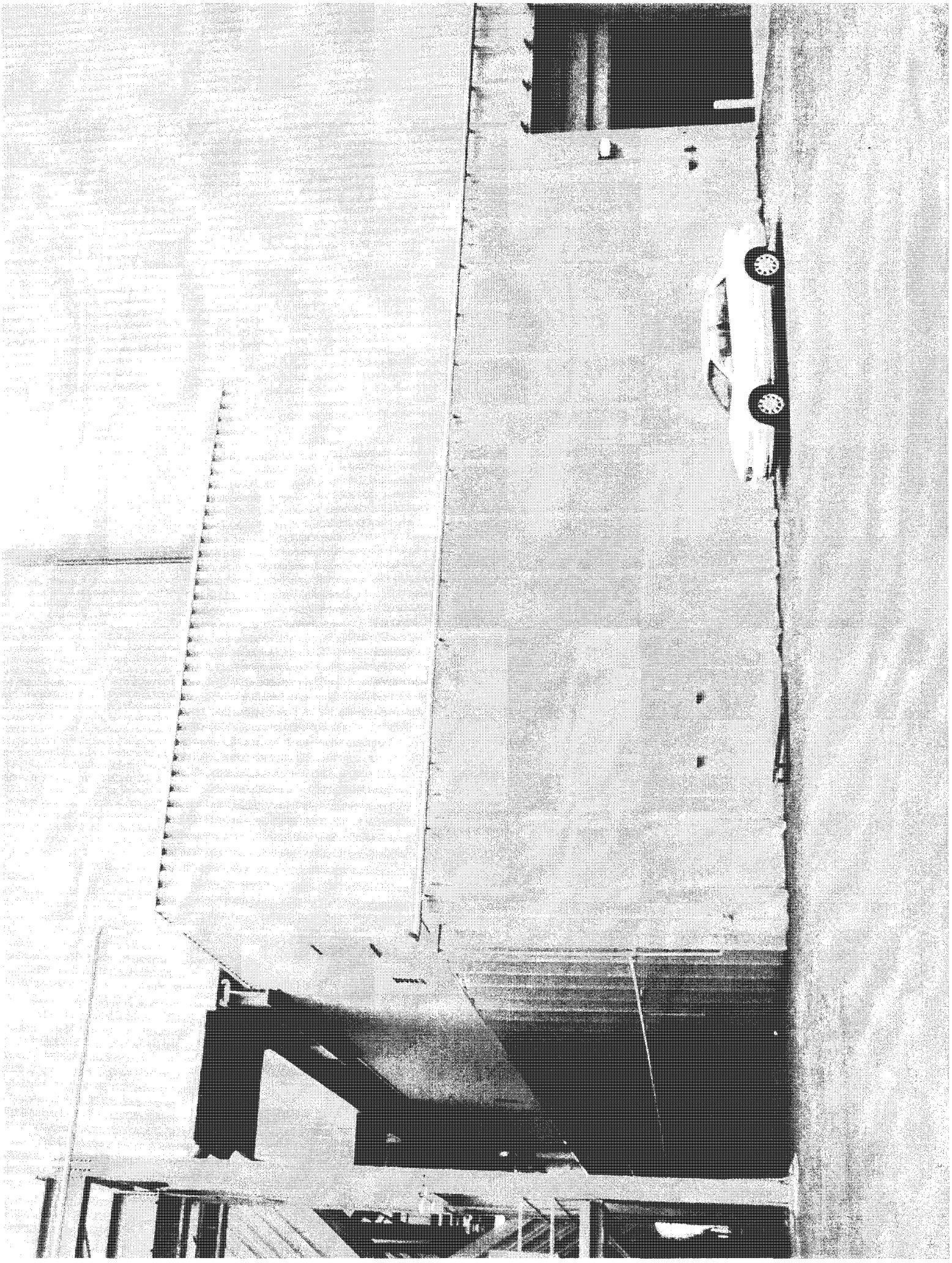

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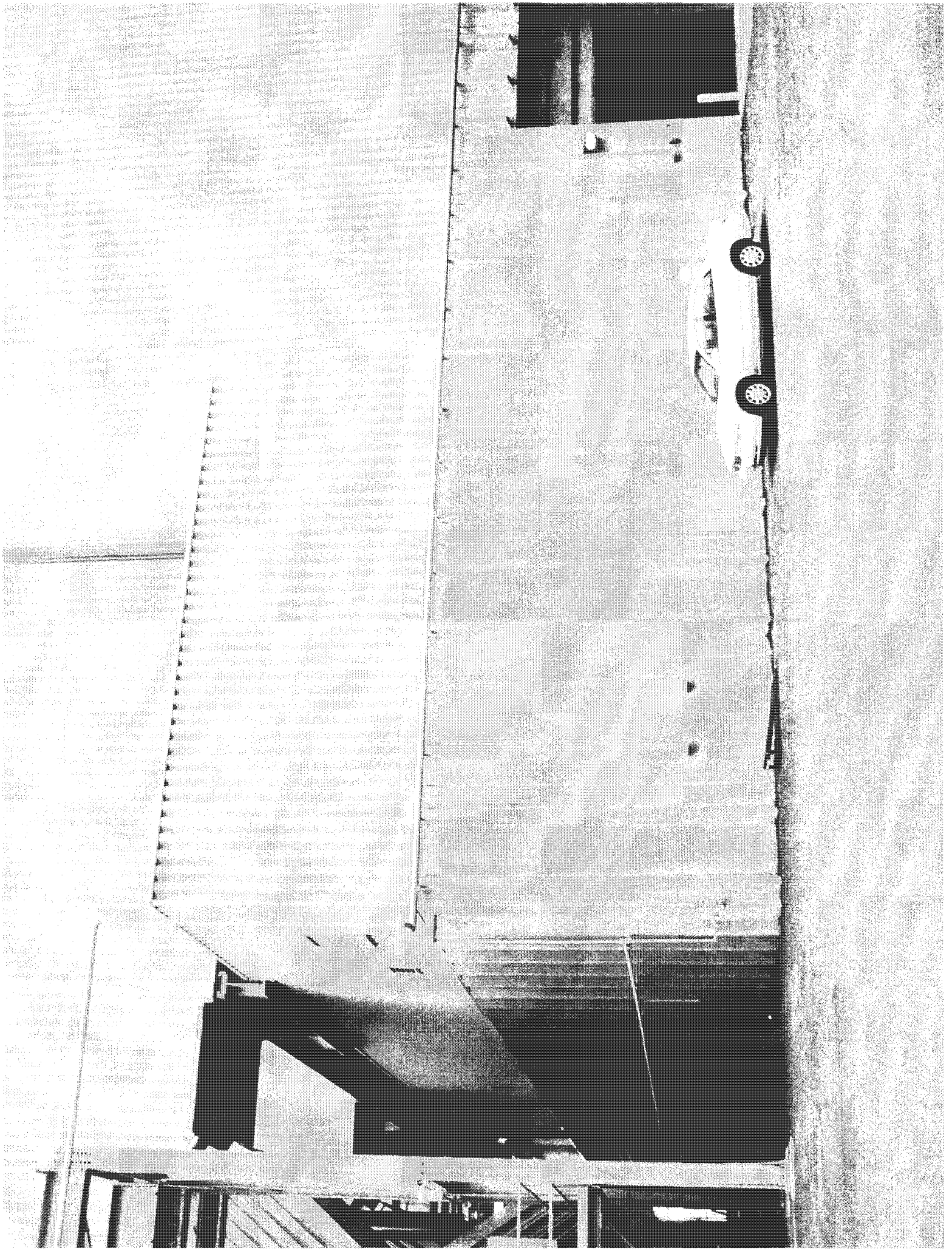

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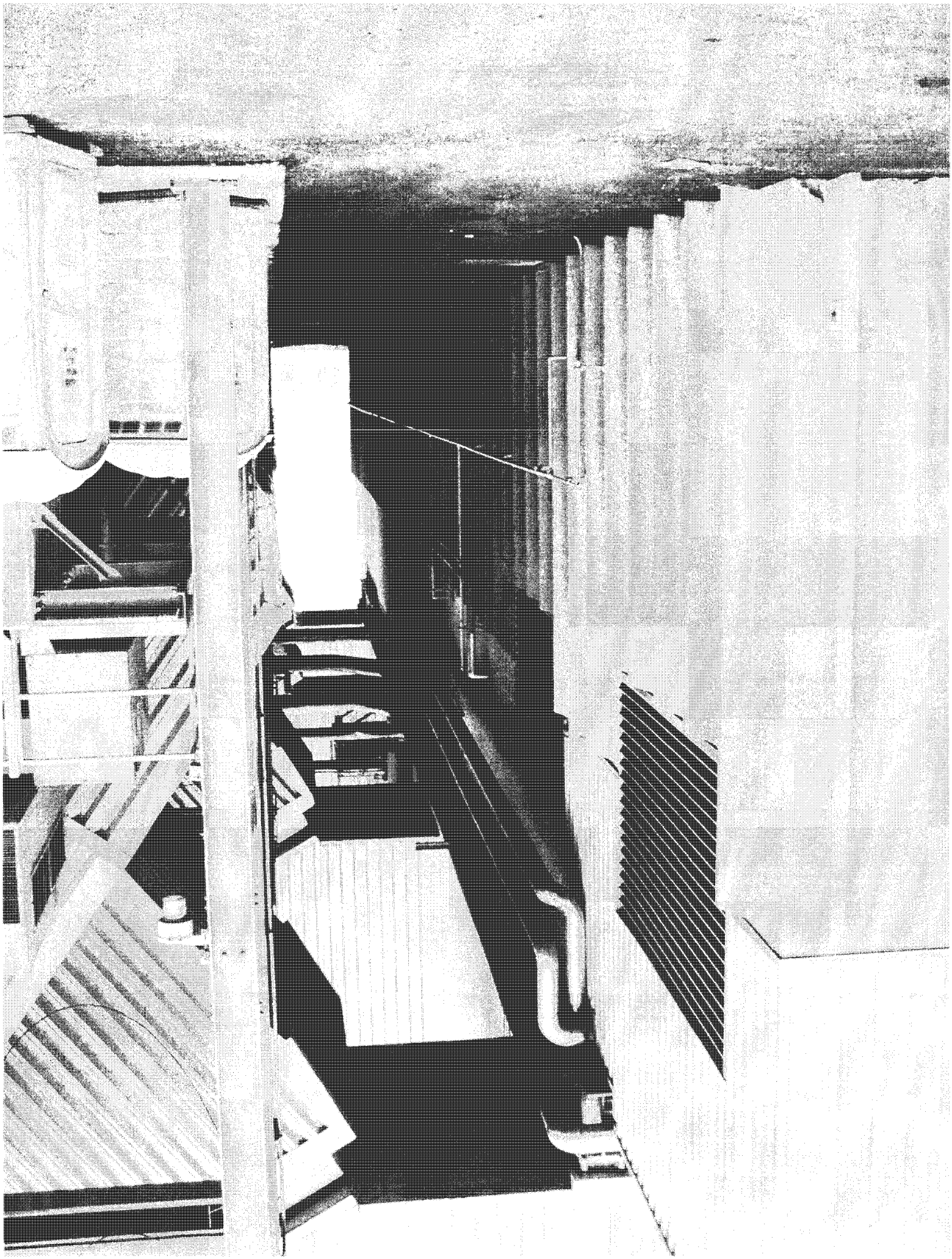

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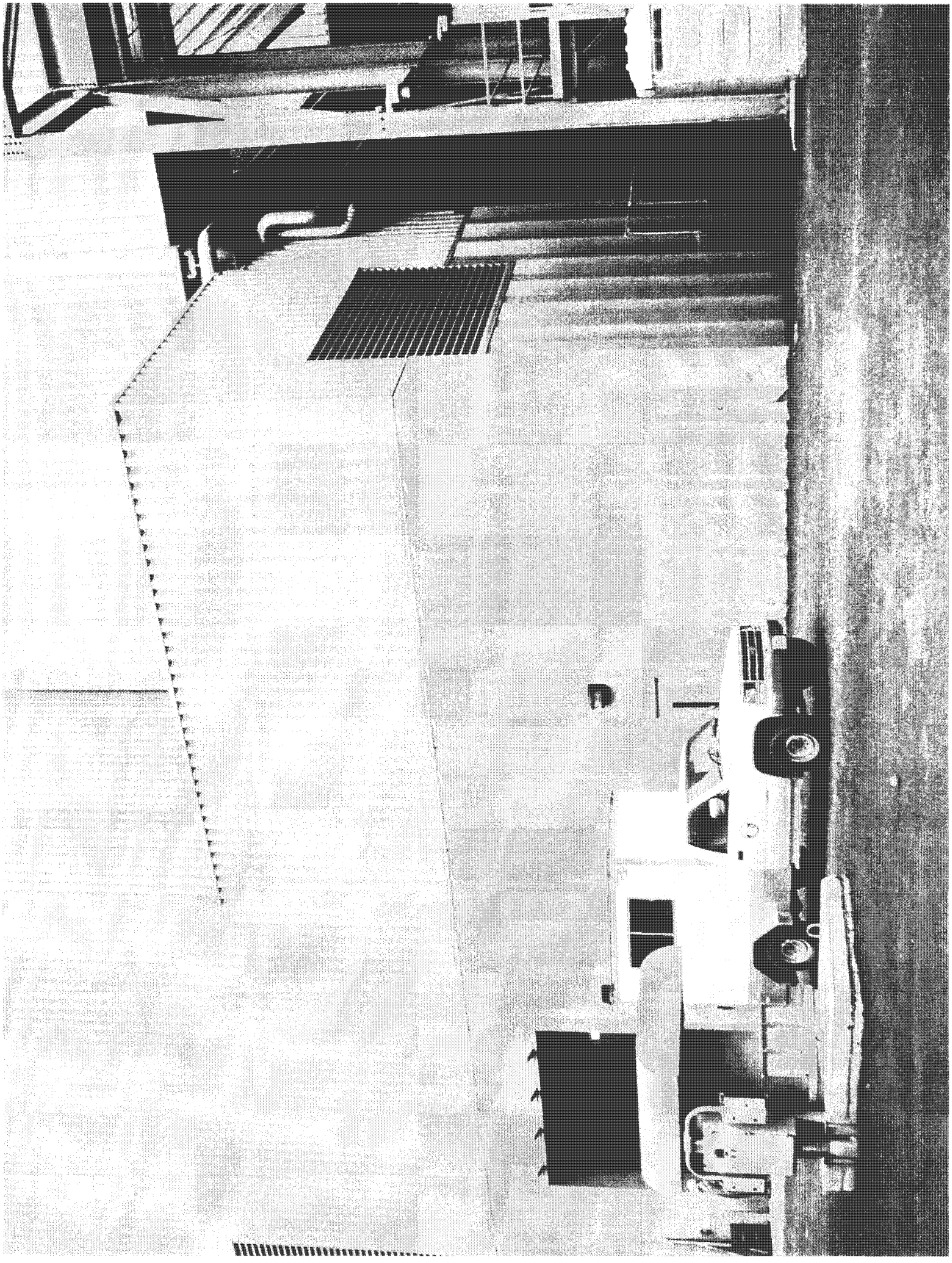

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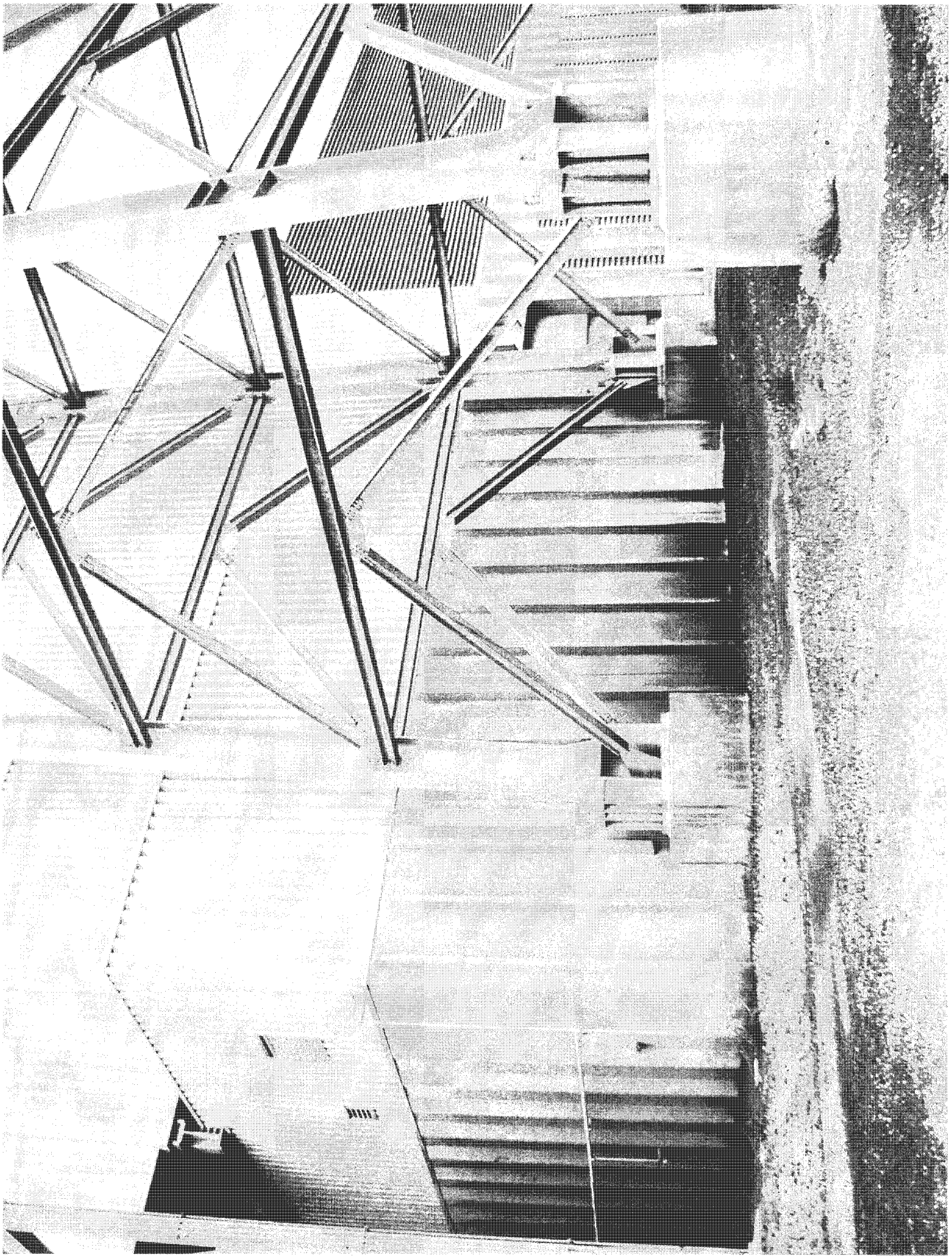

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COMMISSIONING INSTRUCTIONS FOR INTERMOUNTAIN POWER PROJECT ID FAN SYNCDRIVE

The following instructions are designed as commissioning instructions for variable voltage variable frequency SYNCDRIVE. In addition to these instructions there will be a "Drive Data Sheet" with specific rating and set up details for the drive, which is contained within Chapter 4 of this manual.

The instructions assume familiarity with the SIGMA Control System. Read the INSTRUCTION BOOK, SIGMA CONTROLLER TECHNICAL MANUAL, COOLING SYSTEM PLC TECHNICAL MANUAL AND CSP TECHNICAL MANUAL in detail before attempting to commission the drive.

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1. INTRODUCTION 3
1.1. REQUIRED EQUIPMENT 3
1.2. REQUIRED DOCUMENTATION 3
2. PRELIMINARY CHECKS 3
2.1. GENERAL EQUIPMENT CONDITION 4
2.2. INTERCONNECTIONS 4
2.3. PRELIMINARY CHECKS WITH POWER OFF 4
2.4. CHECK LOW VOLTAGE SUPPLY 5
3. POWER ON CHECKS 6
3.1. POWER UP REGULATOR AND GATING POWER SUPPLY 6
3.2. DOWNLOAD SOFTWARE 6
3.3. CHECK DIGITAL I/O RELAY LOGIC 6
3.4. CHECK ANALOGUE I/O LOGIC 7
3.5. EXCITER REFERENCE CHECKS 8
3.6. CHECK DIAGNOSTIC SERIAL LINK 8
3.7. HARDWARE OVERCURRENT CIRCUIT 9
3.8. SUPPLY BREAKER INTERLOCKS 10
3.9. COOLING SYSTEM FILL / CHECKOUT 10
3.10. MAIN ACCB FAST PHASEBACK TIMING CHECK 11
3.11. FIRING PULSE CHECK 11
4. PRELIMINARY POWER ON CHECKS 14
4.1. PHASING CHECKS 14
4.2. DC LINK OPEN CIRCUIT CHECKS 16
4.3. SUPPLY BRIDGE OPEN LOOP SHORT CIRCUIT TESTS 16
4.4. CLOSE LOOP SHORT CIRCUIT TESTS 17
4.5. ENCODER SWITCHING SEQUENCING CHECKS 17
5. SINGLE CHANNEL UNCOUPLED TESTS 18
5.1. SAFETY INSPECTION 18
5.2. MODE 1 CHECKS 19
5.3. STATOR VOLTAGE F/B PHASING & ENCODER ALIGNMENT CHECKS 19
5.4. SPEED REGULATOR CONTROL CHECKS 19
6. SINGLE CHANNEL LOAD TESTS 21
6.1. LOAD TEST PRELIMINARY CHECKS 21
6.2. V/F CONTROL CHECKS 21
6.3. SINGLE CHANNEL LOAD TEST REMOTE MODE 21
7. DUAL CHANNEL NO LOAD TESTS 22
7.1. STOP/START TESTS 22
7.2. OPERATIONAL & STABILITY CHECKS 22
8. DUAL CHANNEL LOAD TEST 23
8.1. FULL LOAD CURRENT CHECKS 23
8.2. BETA AND RECOVERY TIME CHECKS 24
8.3. DRIVE OPERATION 25
9. MISCELANEOUS DYNAMIC TESTS 25
9.1. EMERGENCY STOP 25
9.2. MASTER / SLAVE CONTROLLER SWITCH OVER TEST. 25
10. FINAL PROCEDURES 26

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IP7014923

1. INTRODUCTION

1.1. REQUIRED EQUIPMENT

1.1.1.Dual trace storage oscilloscope with x10, x100 high voltage probes and current probes and differential amplifier.
1.1.2.Two digital multimeters.
1.1.3.Clamp on ammeter: 0-2000A AC & DC capability.
1.1.4.Step down isolation instrument transformer: 2400/120V single phase (for phasing check).
1.1.5.4-20mA DC supply.
1.1.6.0-10V DC supply.
1.1.7.High current link.
1.1.8.Two laptops with ALSTOM CSP and overdrive software and cable for connecting to Sigma regulator, GE FANUC VersaMax PLC, and the HMI.
1.1.9.GE FANUC VersaMax PLC software and programming lead.
1.1.10.Red Lion HMI software and programming lead.
1.1.11.Flow meter with flexible hose and quick disconnect couplings.
1.1.12.High resistance resistor for DC link loading (for low load current around 1.25A – 2.5A). This may not be necessary, as the snubber circuit resistors will be adequate for load provision.

1.2. Required Documentation

1.2.1.Drawing package SYNCDRIVE schematics.
1.2.2.SYNCDRIVE software application block diagrams and SIGMA User program.
1.2.3.System One Line diagrams.
1.2.4.System functional block diagrams.
1.2.5.SIGMA Controller Technical Manual.
1.2.6.CSP Technical Manual.
1.2.7.Cooling system PLC Technical Manual (Data sheets, Components).
1.2.8.System torsional study report.
1.2.9.RED LION HMI Technical Manual / Data sheets.

2. PRELIMINARY CHECKS

Before the SYNCDRIVE equipment is commissioned, ensure the input breaker, output switch, supply transformer and motor have been commissioned as detailed within the relevant sections of their instruction books.

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2.1. GENERAL EQUIPMENT CONDITION

2.1.1.Ensure that the appropriate contract number and serial number have been recorded in the spaces provided on the commissioning report. Use a separate form for each drive or channel.
2.1.2.Check with project manager to ensure that the copies of the contract schematics are current and that they reflect any as-built changes. Check all ECN's are incorporated.
2.1.3.Check cubicles for signs of damage that may have occurred during shipping and installation. Document and report any damage found during this inspection to project manager.
2.1.4.Ensure all components are present, properly mounted and securely fastened. Check all relevant component values against circuit diagram. These components include resistors, capacitors, reactors, fuses, and other major items.
2.1.5.Check all wiring for tightness.
2.1.6.Check all accessible hoses, clamps and fittings for tightness.

2.2. Interconnections

2.2.1.Check connections between drive cubicles. This shall include main bus-bars, auxiliary wiring and ground bus. Ensure that field interconnections are present and completed with good workmanship. Check that the wiring in the drive agrees with the contract schematics. Also check that wires are not damaged and fiber-optic cables do not exceed the minimum bend radius 3 inches and connectors are securely crimped to the cables.
2.2.2.Check connections between the drive line-up and the excitation controller cabling, supply transformer cabling, etc. This shall include main power cables and auxiliary control wiring. Check that all transformer tapings are set correctly. Also check the settings of any timer relays or thermostats.
2.2.3.When relevant, ensure that all field terminations are present and completed with good workmanship.
2.2.4.Ground check. Check that each interconnection section of earth bar link has been made and any ground connections to the cooler cubicle.

2.3. PRELIMINARY CHECKS WITH POWER OFF

Verify the following:
2.3.1.Verify all main power breakers or auxiliary breakers are off.
2.3.2.The motors have been checked and are ready to run.
2.3.3.The water-cooling pumps have been checked and are ready to run.
2.3.4.All the breakers and switchgear has been commissioned and protective relaying is calibrated. Record the settings in the following table:

HV FLC		Amperes
Switchgear CT Ratio		
I>>		Amperes
I>		Amperes
Plug Setting		
Time Multiplier		
Setting sheet attached	YES	NO

2.3.5.All equipment grounding has been inspected and verified.

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2.3.6.All signal grounding has been inspected and verified.
2.3.7.All printed circuit boards have had jumper settings, switch settings and links verified against the drive schematics.

2.4. Check Low Voltage Supply

2.4.1.Check that each breaker operates properly with and without AC power applied to the breakers and that the appropriate input indicates the proper state of the breakers.
2.4.2.Locate and de-energize the sources that supply power to low voltage supply circuits and verify phase sequence for 3 phase sources.
2.4.3.Open the following circuit breakers:

480 VAC supplies
MCB1 – Exciter supply
MCB2 - Gating power supply
MCB3 - Cooling system pump 1 supply
MCB4 – DC reactor fan 1 supply
MCB5 - DC reactor fan 1 supply
MCB6 – Cooling system pump 2 supply

120 VAC supplies
MCB7 –120 VAC normal supply
MCB8 – 120 VAC UPS Sigma power supply
MCB9 – 120 VAC UPS distribution terminal block
MCB10 – 120 VAC UPS magnetic pick up supply (Channel 2 only)
MCB11 – 120 VAC UPS output disconnect supply

Remove the following fuses:
FS9 – Phase reference supply

2.4.4.Locate and energize the source that supplies power to the low voltage control circuits that have been isolated via the breakers and fuses that have been opened.
2.4.5.Using a suitable DVM measure the line to line RMS voltages at the input terminals of the breakers and record them.

For 480 VAC 3 phase circuits (TB1): 456 VAC to 528 VAC. _____V

For 480 VAC 3 phase circuits (TB1A): 456 VAC to 528 VAC ._____V

For 120 VAC circuits (TB2:5-6): 114 VAC to 132 VAC. _____V

2.4.6.Locate and correct any out of tolerance supplies.
2.4.7.Locate and de-energize the source that supplies power to the low voltage circuits.
2.4.8.Replace all fuses.

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3. POWER ON CHECKS

3.1. POWER UP REGULATOR AND GATING POWER SUPPLY

3.1.1.Check that new batteries are fitted in the SIGMA.
3.1.2. With the breakers to the cooling system pumps open, replace fuses and close necessary circuit breakers to power up the SIGMA regulator and associated circuitry. Refer to SIGMA Controller Technical Manual for SIGMA regulator status verification.
3.1.3.Close the gating power supply (GS1) breaker (MCB 2) and verify that the unit powers up properly and that each gate card is energized. Verify that the top green gate power healthy LED is illuminated on each gate card.

3.2. DOWNLOAD SOFTWARE

3.2.1.Compile, download and run the SIGMA application program in the controller using a laptop computer.
3.2.2.Download the HMI Code.
3.2.3.Download the PLC Code.
3.2.4.Download the Exciter Code.

3.3. CHECK DIGITAL I/O RELAY LOGIC

- **Ensure that the input breaker is in the test position or disconnected from the main HV AC power supply.**

3.3.1.When forcing the outputs used for Main Incoming Breaker and Output Breaker control, check the operation of the breaker close and trip circuits.
3.3.2.Using CSP, verify the correct operation of all panel-mounted digital I/O. Refer to SYNCDRIVE schematics for the I/O assignments. This includes:
3.3.3.Verify all Digital Inputs:
3.3.4.Verify all Digital Outputs by forcing them according to the following table.

Bit	M Table
B1.08	M8.0
B1.09	M8.1
B1.10	M8.2
B1.11	M8.3
B1.12	M8.4
B1.13	M8.5
B1.14	M8.6
B1.15	M8.7
B3.0	M8.8
B3.1	M8.9
B3.2	M8.10
B3.3	M8.11

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B3.4	M8.12
B3.5	M8.13
B3.6	M8.14
B3.7	M8.15

To test the digital outputs, display all the outputs as per the above table. Some of these may already be at 1, depending on the state of the drive logic. Set table M9.15 = 1, This will disconnect all the outputs from their ladder program rungs and enable each one to be manually driven. When M9.15 is set all the digital outputs should immediately change state to zero. Setting the tables M8.0 to M8.15 can now manually operate all the outputs. Set each output sequentially and verify it's function per the contract schematics.
Remove all pokes by executing a "halt" and a "run."

3.3.5.Drive ID check

- This test is performed to determine that each channel has the correct identity. Verify that the HMI is reading the correct drive ID for the correct unit/fan/channel, i.e. 1D1 or 1D2 etc

3.3.6.Verify the correct state of all external interlocks and permissives. Check that the sense of each signal is correct and that the signal changes state as the external contacts are opened or closed.
3.3.7.Force digital outputs by editing the SIGMA and checking that pilot relays, contactors and other devices connected to the outputs operate properly.
3.3.8.Check the plug interlocks against the table below. Remove each Type C board plug individually and check that the corresponding address changes from 0 to 1.

Address	Type C Board Plugs
L16809	TB311, TB313
L16810	TB312, TB314
L16811	PL319
L16815	TB315

3.4. Check Analogue I/O Logic

3.4.1.Check the operation and feedback scaling of the analog inputs, outputs, and any interposing transducers or meters.
3.4.2.Analogue Inputs

Word	Range
C14	4-20mA = 150-954 rpm
C15	0-8V = 0-150%
C16	4-20mA
C17	4-20mA

3.4.3.Analogue Outputs

Word	M Word	Range
D0	M10	0-5V
D1	M11	0-10V

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D2	M12	4-20mA
D3	M13	4-20mA
D4	M14	4-20mA = 150-1100rpm
D5	M15	4-20mA = 0-750A AC
D6	M16	4-20mA = 0-5000V AC
D7	M17	4-20mA

3.4.4.Inter Regulator Analogue Torque Reference Test

- The inter-regulator torque reference analogue signals are scaled such that 2-8V are equal to 0-150% of rated motor torque.
- To test the inter-regulator torque reference analogue signals, set M9.0=1 and M11=100%.
- Measure the voltage at the Sigma analogue I/O board TB18-2 with respect to TB18-5. This should read +6.00V. Set M10= -100%, the voltage measured should read –2.0V. This signal should appear at the other Sigma analogue input board TB17-1+ with respect to TB17-1-.
- Make sure that the polarity of the signal is correct.
- If the Sigma of the other channel regulator is energized, check that table G83 (scaled torque reference) reads +10000% for +6.0V input.
- Set M9.0 and M11 to zero.

3.5. Exciter Reference Checks

These tests will check the scaling and operation of the analog reference signal to the exciter and the exciter current feedback.

3.5.1.Ensure the jumpers are set according to the contract schematics.
3.5.2.Ensure the program is downloaded.
3.5.3.Ensure that 480V is applied on the exciter.
3.5.4.Poke M5.0 = 1 to close the exciter.
3.5.5.Poke M6 from 0% to 100% to represent 0-5V output on D0.
3.5.6.Complete the data table on the spreadsheet.
3.5.7.Prove that when the current trip level in the program is exceeded that the excitation controller trips.

NOTE

For these tests, remember that if the inter-regulator cables are connected that 480V will appear in the other regulator cabinet, this could be dangerous if personnel are working therein.

3.6. CHECK DIAGNOSTIC SERIAL LINK

3.6.1.Complete a visual check to ensure that the routing of all diagnostic cables is as shown on the schematic diagrams.
3.6.2.Check that the gate cards and distribution boards are powered up and that green LED is lit indicating fiber optic cable healthy.
3.6.3.Check that the HDLC enhancement card is healthy (L7201 = 1). Monitor the serial link statistics in L7284 onwards. There should be no time-outs, CRC errors etc. The number of TX and RX messages should be incrementing. Check that L7308=1.
3.6.4.If all the above is healthy, check that the relevant red LED on each gate card and distribution board is flashing,

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indicating the correct tributary number (See hardware product data for each board on how to determine tributary number).
3.6.5.If all the above is not healthy, check the fault word (L7309). Refer to module L73 documentation for the meaning of the fault code.

3.7. Hardware Overcurrent Circuit

3.7.1.The following method should be used to verify the correct operation of the hardware overcurrent trip circuit.

- Disconnect the cables attached to the Type-C interface board at terminal block TB313-1, 2 & 3. This is the supply converter current feedback.
- Connect a variable DC power supply with an adjustment range of at least 0 to 2 V DC to terminal TB313-1 and TB313-3 with TB313-1 positive with respect to TB312-3.
- With the Sigma program running and showing no trips (alarms are acceptable), slowly increase the DC voltage from zero volts until the drive trips on hardware overcurrent.
- The drive will show "SUPPLY 1 OC" trip before tripping on "HARDWARE OC".
- Ignore the first overcurrent trip (as this is a software-generated fault) and continue to increase the voltage until a hardware overcurrent is indicated.
- Repeat this test to ensure that the trip is occurring at the same voltage.
- Check also that A32.7 goes to zero when the hardware overcurrent relay on the type C opens.
- Record the DC voltage level at which the drive indicated over current trips.

	SUPPLY 1 OC	HARDWARE OC
Channel 1	V DC	V DC
Channel 2	V DC	V DC

- The CT's are generally sized to produce about 0.6 volts at these terminals when the drive is operating at full load; the hardware overcurrent trip should occur somewhere between 1.0 and 1.1 Vdc.
- Repeat the above tests for the machine converter current feedback(s) using TB 313:11,12 and 13 (TB 313:11 positive with respect to 13).

	SUPPLY 1 OC	HARDWARE OC
Channel 1	V DC	V DC
Channel 2	V DC	V DC

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3.8. Supply Breaker Interlocks

3.8.1.All the following checks should be done with the main AC feeder de-energized. Check that the interlocks from the breaker operate correctly

- Breaker Closed and Open

3.8.2.Check the breaker trips when the hardware over-current relay on the Type C interface board is de-energised.
3.8.3.Check that when E-Stop is depressed that the relevant channel trips and that the main breaker trips.

3.9. Cooling System Fill / Checkout

3.9.1.Pressurize the cooling system to at least 10 PSI. Leave the system pressurized for a minimum of 1 hour and then check the pressure to verify the absence of leaks.
3.9.2.Open \ close appropriate valves and fill the cooling system with water. The initial fill should be made with clean de-ionized or de-mineralized water to reduce the time needed to reach the required conductivity level and to prevent a reduction in the life of the de-ionization tank.
3.9.3. Check the setting of the pump motor and heat exchange fan over-current device, the data of set up shown on schematic drawing.
3.9.4.Energize each pump motor individually and verify proper motor rotation. Continue to add water to system as necessary. Measure motor current and verify that it does not exceed the nameplate rating. **WARNING: Serious damage will result if the pump is run dry.** The pump must be primed before running.
3.9.5.Operate a single pump until all of the air in the cooling system has been purged. Alternate from one pump to the other periodically until the air is removed.
3.9.6.Verify consistent coolant flow in all parallel cooling paths using an inline flow meter with flexible hose and appropriate quick disconnect connectors. This would include flow through the SCR modules, surge circuits, etc.
3.9.7.Energize control power to the cooling system PLC and auxiliary equipment. Use the GE Fanuc PLC to check the function of all of the external sensors and devices. Ensure that the pumps can be controlled by forcing the appropriate PLC address table. Confirm that each of the cooling system protective devices (e.g., conductivity monitor, flow switch, thermostat, reservoir level indicator, moisture detector) functions and that it is recognized by the PLC. Cause each of these devices to activate by adjusting set points, de-energizing the pumps, etc (as necessary). Verify the function of all alarms, trips and interlocks. Calibrate flow and pressure transducers as needed for proper operation.
3.9.8.Check the setup of the conductivity analyzer. Reprogram the conductivity analyzer if necessary.
3.9.9.Verify the operation of all sensors located on the customer side of the heat exchanger (mounted in cooling system cubicle) and calibrate the devices as needed for proper operation. Clean the Y-Strainer and check the paper filter for debris and replace or clean the filter as needed.

Cooling System Settings

Alarm/Trip	Setting	Units
Low Flow Alarm		GPM
Low Flow Trip		GPM

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Conductivity Alarm	0.5	µSiemens
Conductivity Alarm Reset	0.3	µSiemens
Conductivity Trip	1.0	µSiemens
Conductivity Trip Reset		µSiemens

3.10.MAIN ACCB FAST PHASEBACK TIMING CHECK

3.10.1.To achieve the desired level of protection of the supply converter it is imperative that the correct discrimination exists. Essentially the converter must be phased back and current extinguished before the ACCB main poles part.
3.10.2. The early openeing contact (from the switchgear) sends an early trip signal to the drive, before the main breaker poles open, on detection of a fault. The drive immediately phases back the converter to avoid thyristor damage by the transfer of AC side arc voltage.
3.10.3.It is essential that the system be checked to ensure the necessary trip timing margin exists.
3.10.4.Connect a scope across the breaker feedback signal (A32.07) and the second channel to the supply voltage feedback. Using the "one-shot+ feature of the oscilloscope, trip the breaker from the various sources and record the time difference between the falling of the feedback status and the loss of mains supply
3.10.5.This test will have to be completed for every possible non-drive initiated trip that could cause the breaker to trip i.e. local trip, protection trip etc.

	Channel 1	Channel 2
Local Operator Trip	msec	msec
O/C Protection Trip	msec	msec
Drive Trip	msec	msec

3.11.Firing Pulse Check

3.11.1.This test is performed with the main AC power input breaker open and the phase reference supply energized (necessary for a pulse release).
3.11.2.A means for energizing the pulse inhibit digital input (A32.7) without closing the main AC supply breaker will be required (necessary for a pulse release). This can be achieved by applying a temporary jumper on the relevant terminals.
3.11.3.Remove the pulse amplifier cable from the Machine Bridge PAB2 PL2.

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3.11.4.Two amplified oscilloscope current probes or equivalent passive current probes will be required to monitor the thyristor gate current. All of the following checks are completed by measuring the thyristor gate current.
3.11.5.Configure the drive for firing pulse test mode by using the CSP monitoring mode to make the following pokes:

M3.4 = 1	**INHIBIT MODE 1 ENCODER**
M3.5 = 1	**INHIBIT MODE 2 ENCODER**
M5.6 = 1	**MASK SUPPLY REFERENCE LOSS**
M5.8 = 1	**FORCE PULSE RELEASE**

3.11.6.To remove pulses, set M5.8 = 0.
3.11.7.Ensure that only the Supply Converter pulses have been released by checking the amber LED's on the Converter gate boards.
3.11.8.Plug the pulse amplifier cable from PAB2 PL2 in again.
3.11.9.Release pulses again and ensure that both Converter and Inverter Bridges are firing.
3.11.10.Check the gate current waveform on **every** thyristor for the supply bridges and the motor bridges. Release pulses and verify the correct duration, appearance and phasing of each thyristor-gating signal in every converter. Verify that the gate current flows into the gate terminal of each thyristor (White lead flows into the device). In particular, check each gate pulse waveform for:

- Pulse polarity. [Positive current into gate (white wire)]
- Pulse train duration [120°]
- Width of individual pulses in pulse train. [15µs ± 0.5µsec]
- Duration between pulses [125µsec]
- Peak gate current amplitude (leading edge). [>2.0A]
- Gate current amplitude (back porch). [>0.5A]
- Rise time of leading edge. [<1µsec]

3.11.11.Refer to the typical waveforms. Fig 3 (lower trace) shows a typical individual gate current pulse on a 2µS per division time scale. The current amplitude varies from one thyristor to another depending on its precise gating characteristic. For completeness, the upper traces of Figs 3 shows the corresponding gate to cathode voltages. A voltage trace would need to be examined only if there was doubt about the correctness of a current trace.
3.11.12.Verify that the correct phase relationship exists between each arm in the supply converter.
3.11.13.Verify that the correct phase relationship exists between each arm in the machine inverter.
3.11.14.Check the pulse sequence is as follows:

Pulse 1 to leads pulse 2 by 60°
Pulse 2 to leads pulse 3 by 60°
Pulse 3 to leads pulse 4 by 60°
Pulse 4 to leads pulse 5 by 60°
Pulse 5 to leads pulse 6 by 60°
Pulse 6 to leads pulse 1 by 60°

60° = 2.78 msec for a 60Hz system frequency.

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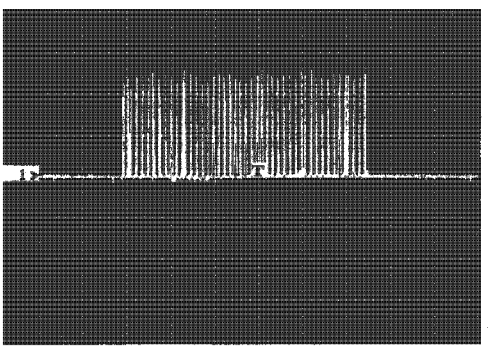

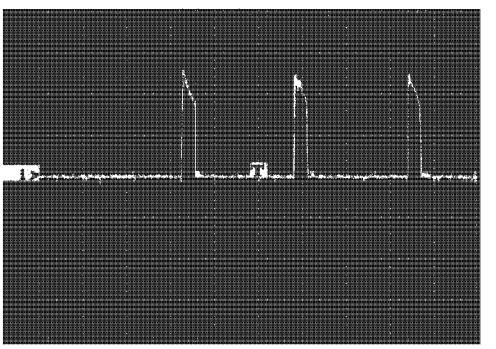

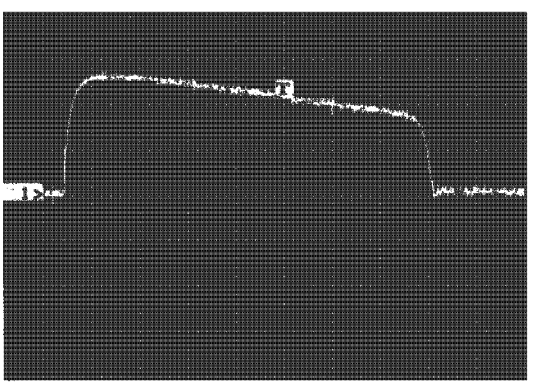

3.11.15.Check that the gate pulses at the PIB's (20x4504) test points (TP's) to the corresponding Arms of the Bridges are perfectly in phase with each other. This is to ensure that when the phasing checks are done, that measurement of gate pulses from the PIB's are reliable. Recordings should agree with the following:

PIB TP1-TP5	ARM 1	Va - Vc (Vac)
PIB TP4-TP5	ARM 2	Vb - Vc (Vbc)
PIB TP7-TP5	ARM 3	Vb - Va (Vba)
PIB TP2-TP5	ARM 4	Vc - Va (Vca)
PIB TP6-TP5	ARM 5	Vc - Vb (Vcb)
PIB TP8-TP5	ARM 6	Va - Vb (Vab)

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4. PRELIMINARY POWER ON CHECKS

NOTE: Main AC power will be applied to the supply converters for the completion of the following tests.

- The supply circuit breaker over-current protection must have been commissioning and checked prior to commencement of the following tests.
- The input breaker trip circuit of the drive must also be checked and functional.
- The conductivity of the drive's coolant must be within operational limits.
- A single phase isolating transformer will be needed to step the input line-to-line voltage down.
- Every converter cabinet door must be closed during the test.

4.1. Phasing Checks

4.1.1.Disconnect the DC power circuit at the machine bridge side of the DC link choke (power bus terminals DC2 and DC4).
4.1.2.Close the transformers disconnect for the channel under test and open the transformer disconnect for the other channel. Close the input breaker and measure the no-load voltage at the inputs to each supply bridge. Verify the correct phase rotation of the supply voltage (A phase leads B phase, B phase leads C phase).
4.1.3.Open the input breaker when the test is completed.
4.1.4.Connect an isolation transformer and oscilloscope as shown in Figure 4.

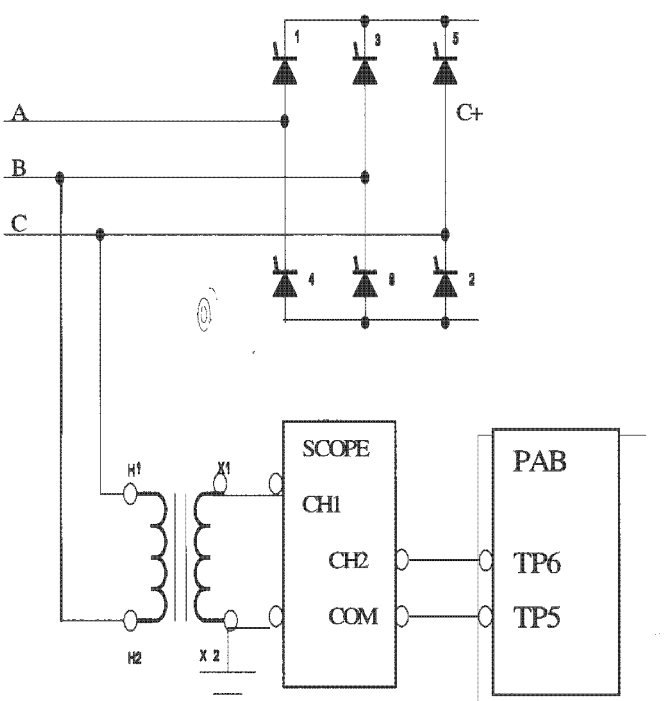

Figure 4

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4.1.5.Disable the Machine Bridge firing pulses by unplugging the Inverter pulse amplifier lead (PL2) at PAB2.

4.1.6.The test points on the pulse amplifier board must be used to monitor gating pulses instead of the oscilloscope current probe when operating above 600V.

4.1.7.Connect the secondary voltage of the isolation transformer to the scope along with TP6-TP5 on PAB1. Close the input breaker.

4.1.8.Configure the drive for Open Circuit Test by using the CSP monitoring mode to make the following pokes:

M3.04= 1	**INHIBIT MODE 1 ENCODER**
M3.05 = 1	**INHIBIT MODE 2 ENCODER**
M3.07 = 1	**INHIBIT START FAIL**
M2.12 = 1	**FORCE OPEN LOOP**
M2.03 = 1	**FORCE LOCAL MODE**
M2.05 = 1	**FORCE LOCAL START**

This will enable open loop test mode.

4.1.9.To release pulses press the set M2.5 = 1, to inhibit pulses set M2.5 = 0. Gating pulses should be released and L12614 (Alpha) should be at 150°.

4.1.10.L12614 should agree with the angle by which the leading edge of the firing pulse train lags the positive going zero crossing of the supply voltage. See Figure 5.

4.1.11.If the values do not agree, adjust the value of L12101 until they do.

4.1.12.Adjust the open loop voltage reference, L12612, to change the firing angle while monitoring Supply Alpha Reference in L12614.

4.1.13.The correct value of offset should then be set permanently in the links program of the drive.

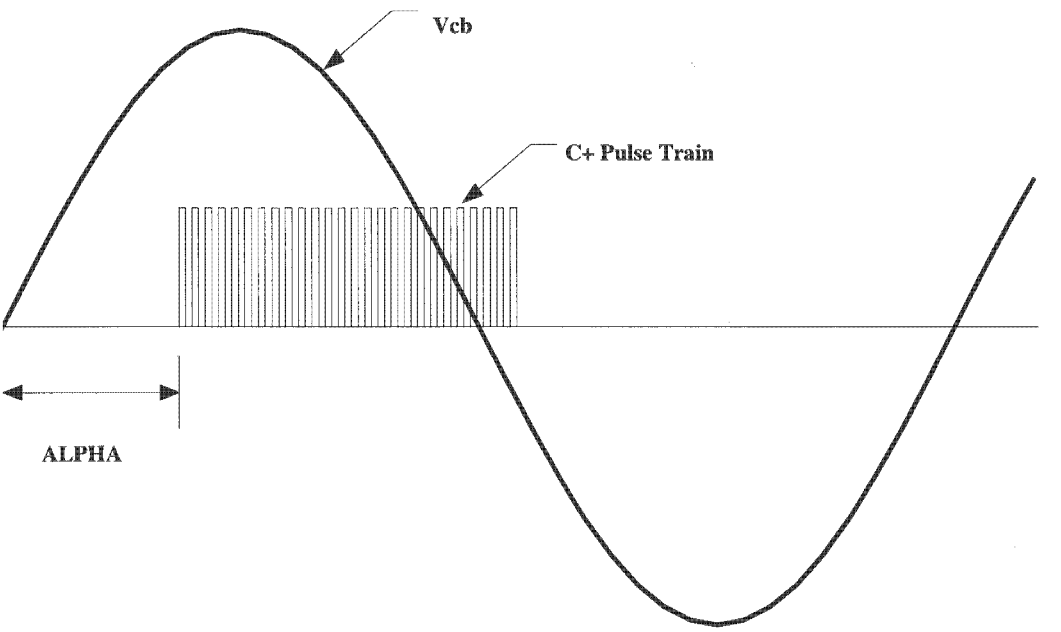

Figure 5

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4.2. DC Link Open Circuit Checks

4.2.1.Complete these tests using the same pokes as 4.1.9 above.
4.2.2.Ensure the input breaker and no load disconnects are open.
4.2.3.Connect the light load resistor between DC+ and DC- link bus on the under test channel.
4.2.4.Connect high voltage probes to a scope between DC+ and DC- link bus on the channel under test.
4.2.5.Close no the load disconnect of the channel under test and then close the input breaker.
4.2.6.Release the firing pulses for the channel under test.
4.2.7.Phase back to L12612 = -100%, disable pulses, open the input breaker and disconnect and remove the light load resistor.
4.2.8.Starting at L12612 = -100%, incrementally increase the value of L12612. Plot the resulting DC link voltage as a function of alpha. Ensure the DC link voltage rises smoothly whilst increasing the voltage to the maximum no load voltage.
VDC = 1.35 x VAC

4.3. Supply Bridge Open Loop Short Circuit Tests

- The purpose of the Open Loop Test is to ensure that the current feedback loop is complete.
- With the input breaker de-energized connect a cable capable of handling 1100A DC between power bus terminals DC2 and Channel 1 negative.
- NOTE: The bus bar joints must be re-torqued to the correct setting requirement.
- Arrange for water flow through the external cooling loop of the heat exchanger.
- Disable the Machine Bridge firing pulses.
- Place a clamp-on current meter around the link connection cable between the DC positive bus and negative bus.
- Connect a scope with an active/passive current probe to the type-C PIB current feedback jumper on TB313:3-7.
- **Note**: L12612 is a voltage reference. Since this test circulates current through a virtual short circuit, very small voltage increases will result in significant current increases. The value in L12612 should be changed in very small increments i.e. 1 degree at a time.
- Poke L13103 = 50% (Trip Threshold).
- Close the input breaker to energize the supply
- Set the M tables as described in the previous tests. The alpha angle, L12614 should be at -165°. **Slowly** increment L12612 while monitoring L12614, and the link current on the clamp-on current meter and the oscilloscope.
- Current should just begin to flow at alpha = 120°, and should just become continuous at alpha = 90°.
- Monitor the current feedback on the clamp on meter and confirm that the value of the filtered supply current feedback L13109, as a percentage of the DC link current rating of the drive (check software title sheet for rating), agrees with actual DC link current.
- Set open loop reference, L12612 = -100% and release the Supply Bridge pulses with the drive in open loop control mode.
- Phase the drive forward using the open loop reference until 10% rated current is achieved
- Check current scaling (L13101) and readjust if necessary.
- Using the oscilloscope monitor the current ripple. This can be accomplished using the scope or connecting an AC current probe around the DC Link short. It should be uniform and stable.
- Record the current f/b with respect to alpha at various positions.

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- Phase the drive back to zero current (L12612 = -100%).
- Open the input breaker.
- Remove all pokes by issueing a halt/run.

4.4. Close Loop Short Circuit Tests

4.4.1.Repeat the above tests with the Sigma in the closed loop current control mode. In this mode the current reference (L12601) is input directly into the current reference data table and the current is regulated to that value (in the open loop mode the current was controlled by manually changing the alpha angle).
4.4.2.Make the following pokes:

M3.04= 1 INHIBIT MODE 1 ENCODER
M3.05 = 1 INHIBIT MODE 2 ENCODER
M3.07 = 1 INHIBIT START FAIL
M2.04 = 1 FORCE OPEN LOOP
M18 = 0OL I REF
M2.03 = 1 FORCE LOCAL MODE
M2.05 = 1 FORCE LOCAL START

4.4.3.Poke L13103 = 50% (Trip Threshold).
4.4.4.To release pulses set M2.05 = 1. To inhibit pulses set M2.05 = 0.
4.4.5.Check that the current is smoothly controlled and that the filtered current feedback matches the actual current.
4.4.6.With approximately 30% current flowing, reduce the Supply convertor Overcurrent setting until just below 30% and verify that the "SUPPLY CONV INST O/C" trips the drive.
4.4.7.Take the current up to any value below drive rating and look for any abnormalities.
4.4.8.Open the input breaker. Disable test equipment and temporary links across main bus.

4.5. Encoder Switching Sequencing Checks

4.5.1.With the motor uncoupled from the load rotate the shaft in the forward direction while monitoring the encoder feedback. Verify that the correct encoder patterns are received as per SIGMA Module Manual L139V1, Absolute Encoder Feedback. Ensure that for both channels:
4.5.2.L13907 counts through 0, 1, 2, 3, 4, and 5 when the motor is moving in the forward direction. If the count is backwards, swap the wiring of 2 encoders.
4.5.3.Input to A32.1 leads the input to A32.2 by 120° electrical.

- Input to A32.2 leads the input to A32.3 by 120° electrical.
- The inter-channel electrical phase displacement between the Encoders (Ch1 A32.1- Ch22 A32.1) is equal to the motor winding electrical phase displacement.
- If any of the above criteria is not met, ensure the encoder ring is set up correctly.

4.5.4.Measure the encoder pulses at their input to the panel and ensure that they are switching between 0V & 20V-24V DC. Ensure the steps are square and the mark to space ratio is 1:1.
4.5.5.Repeat 4.5.2, however measurement must be made at the Customer I/O board Inputs. If the "OFF" position does not return to zero, then a 12kΩ resistor will need to be wired in between the input and the 0V rail.

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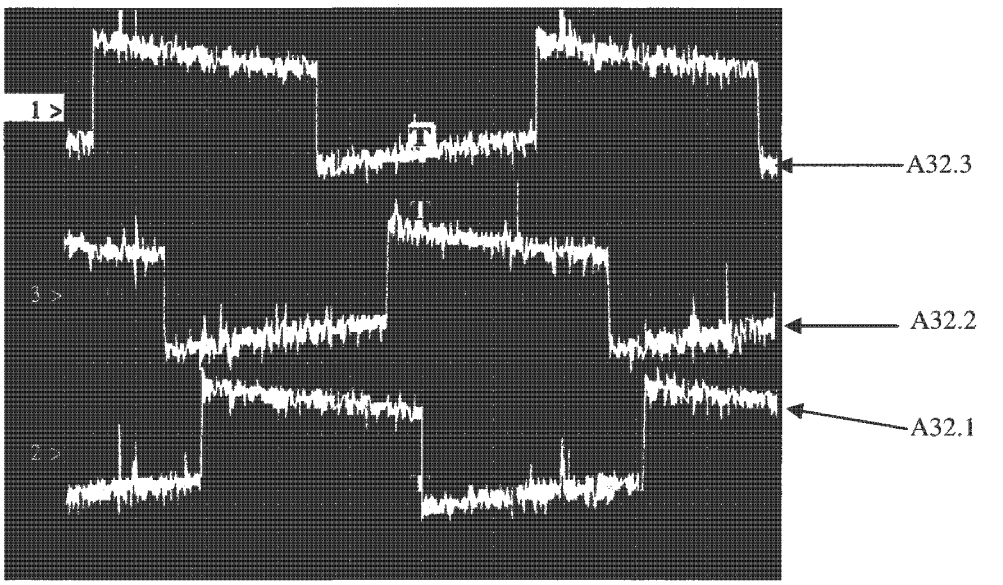

5. SINGLE CHANNEL UNCOUPLED TESTS

5.1. Safety inspection

5.1.1.Before the complete system is energized and run with an uncoupled motor, a safety inspection must be made to ensure the safety of personnel and equipment. Make sure the following requirements have been met:
5.1.2.The motor winding and air-gap must be free of foreign objects.
5.1.3.The motor bearing lube oil system must be ready for service and able to be checked for proper operation as soon as the motor is started.
5.1.4.The motor rotor must be able to turn freely when rotated by hand or with a barring tool.
5.1.5.The motor coupling must be "split" and the coupling shroud on the motor half-coupling made captive so it cannot connect the motor shaft when the motor is running.
5.1.6.The area around the motor and driven machine should be roped off and workers in the vicinity alerted to stay clear of the equipment during the test runs. If necessary, assign a worker to stand watch over the area.
5.1.7.As soon as power is applied to the motor, a qualified person must be ready to inspect the motor for the rotation of the bearing oil rings, abnormal vibration, mechanical noise, temperature, and correct direction of motor rotation. If any abnormal conditions exist, the motor should be stopped immediately and the cause of the abnormal condition must be corrected.
5.1.8.After all of the above precautions have been taken, the system can be operated with the uncoupled motor in accordance with the following testing:
5.1.9.The initial machine control checks are made with the motor de-coupled from the load with the drive in Local Mode by selecting select switch Local / Remote to the Local position.

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IP7014939

5.2. Mode 1 Checks

5.2.1.Start the drive, at the keypad, with a speed reference of 5%. If the motor turns in the wrong direction or rocks back and forth it will be necessary to "roll" the encoder leads at the input to the drive. Repeat this process until the motor reliably starts and turns in the correct direction. (L13921=1 Enable Mode 1). The following Manual pokes will be needed:

M2.3 FORCE LOCAL MODE
M2.5 = FORCE LOCAL START
M4 CSP TEST SPEED REFERENCE

5.3. Stator Voltage F/B Phasing & Encoder Alignment Checks

5.3.1.Start one channel with a speed reference between 7% and 8%.
5.3.2.Ensure the stator voltage feedback, L12305, is between 7% and 8%, and that the polarity thereof is positive.
5.3.3.Ensure that the speed feedback L13924 is correct and positive for forward rotation of the motor.
5.3.4.Slowly increase the speed reference to approximately 12%. At approximately 10% speed the drive should smoothly change to Mode 2. Check L13921 = 1 (enable mode 1) and L13921 = 0 (enable mode 2). If the drive does not go into Mode 2, bounces between modes or is running roughly 15%, then the machine alpha offset angle must be adjusted. The value will be one of the following: -120°, -60°, 0°, 60°, 120°, or 180°.
5.3.5.Monitor the stator voltage feedback with respect to the encoder signals.
5.3.6.The encoder signals are square waves whose rising edge must match the positive going zero crossing of the corresponding stator voltage feedback signal.
5.3.7.Start with encoder (A32.1) and find the stator voltage feedback signal (measured at the input to the Type-C power interface board) that satisfies 5.2.6. Once this has been determined stop the drive and move the stator signal that matched encoder to A phase input on the Type-C, and so on.
5.3.8.Check the phase rotation of motor field exciter.
The phase rotation is correct:
If the field voltage decreases while the field current remains constant and the speed increases.
For the smallest excitation reference for a particular phase sequence.
The phase rotation is opposite to the motor rotation. If this does not occur stop the motor and reverse any two of the three leads going to the exciter and repeat the check for the proper phase rotation.
5.3.9.Repeat the above for the other channel.
5.3.10.Once this is satisfactory, have the motor aligned and coupled.

5.4. Speed regulator control checks

5.4.1.Accelerate the motor to maximum speed. To accomplish this:

M2.3 FORCE LOCAL MODE
M2.5 = FORCE LOCAL START
M4 LOCAL TEST SPEED REFERENCE

5.4.2.Start the drive with a 20% speed reference. When the drive reaches about 30% speed, raise the reference up to 100%. Press the Stop button to finish the testing.
5.4.3.Check the response of the speed regulator and make any necessary adjustments to the PID control loop. In order to achieve this, start the drive and let it run up to minimum speed. Apply a step input into L2204 (Direct Jog Input) and ensure that the drive does not go into current limit (L2126). Monitor the speed feedback signal, L2117, using an oscilloscope attached to a spare analogue output configured to read L2117 by poking to .

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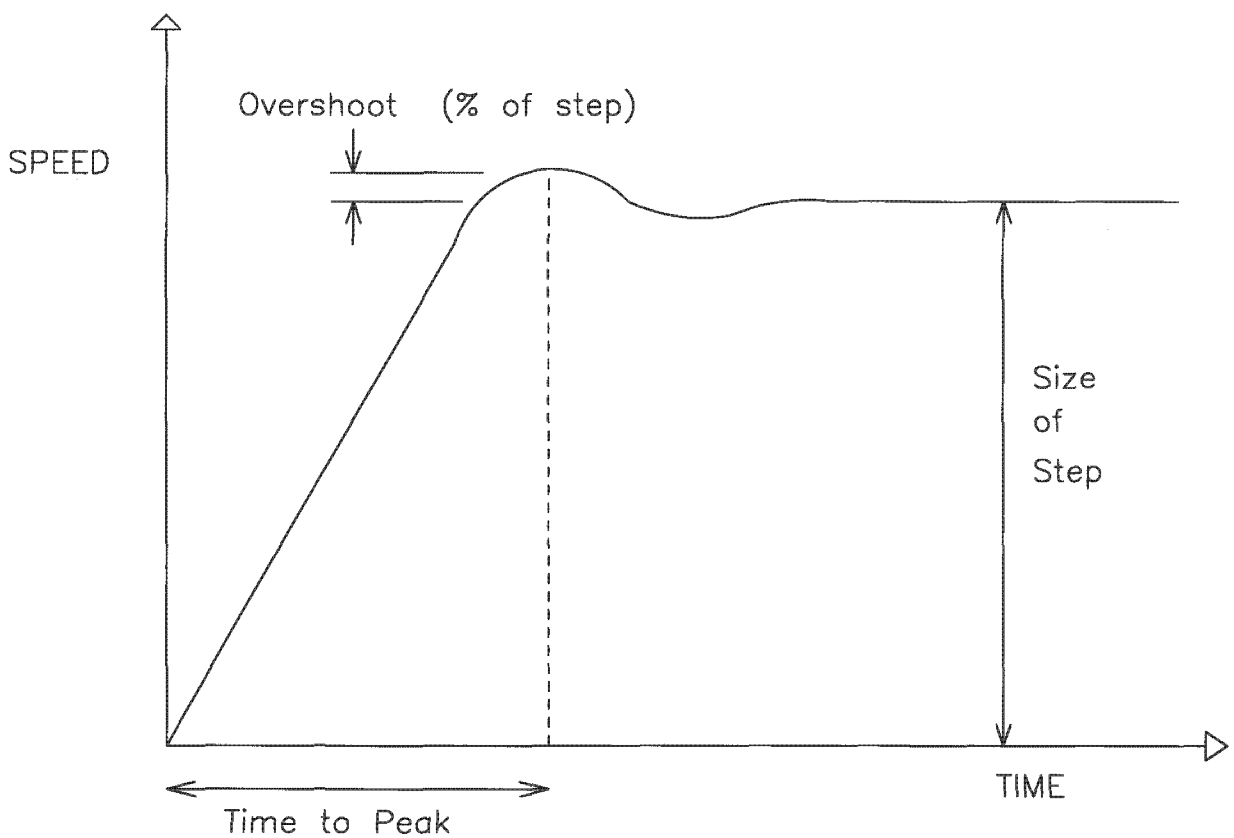
E26 = 76 SCOPE 2 LETTER
E27 = 2117 SCOPE 2 ADDR
E17 = 3052 SCOPE 2 SCALAR
E18 = 0 SCOPE 2 OFFSET

Examine the response of the speed to the step reference (see Figure below). Check values are as given in the Drive Data Sheet.

5.4.4.Run the drive at various speeds throughout the control range and apply step inputs of 1% of top speed. This is carried out by writing step changes into L2102, Test input, (1.00% = step size of 1% of top speed) while the drive is running. If the drive goes into current limit during the step, reduce the size of the step until it does not. Monitor the speed feedback signal, L2117, using an oscilloscope attached to a spare analogue output configured to read L2117. Examine the response of the speed to the step reference (see Figure below). Check values are as given in the Drive Data Sheet.



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6. SINGLE CHANNEL LOAD TESTS

6.1. Load test preliminary checks.

After the motor has been coupled to the load, for the safety of the apparatus and personnel, review the following requirements to ensure they have or will be met:

6.1.1.The alignment between the half-couplings of the motor and the driven machine was carefully checked and is within the limits required by the coupling manufacturers or machinery manufacturers, whichever limits are more stringent.

6.1.2.The coupling has been lubricated in accordance with requirements of the manufacturer.

6.1.3.If possible, the coupled motor and driven machine have been turned by hand to see that they rotate freely.

6.1.4.The operating personnel responsible for the system on hand and have verified that the driven machine is ready to be operated.

6.1.5.Review the previous section on precautions for running the uncoupled motor and be ready to observe the applicable precautions.

6.2. V/F Control checks

6.2.1.Check that all power breakers for the drive are open. This includes Input breaker, no load disconnect switch and the output breaker.

6.2.2.Reset the regulator. If any errors are displayed, they must be corrected before proceeding to the next step.

6.2.3.Set speed reference to 20%. Verify that the drive is in the Local.

6.2.4.Press the Start button to start the drive. The motor should accelerate to min speed of its maximum rated speed.

6.2.5.With the drive running increase Speed Reference, M4, to 40%, 60%, and 80%, use an oscilloscope to measure the stator voltage and frequency. The calculated stator voltage/frequency ratio (Sigma data table L12304) should agree with the measured results. If not adjust the stator voltage feedback scalar (L12301) until the correct V/F ratio is obtained.

6.2.6.If the operation of the drive is satisfactory at this point, gradually bring the motor up to maximum speed and test the motor at top speed.

6.2.7.Check the response of the V/F regulator and make any necessary adjustments to the PID control loop.

6.2.8.Repeat for the other channel.

6.3. Single channel load test Remote Mode

6.3.1.This test presumes that all the PLC I/O has been checked and is correct and the drive default speed is set to about 20%.

6.3.2.Clear any alarms. The drive Ready light should come on.

6.3.3.Ensure that the other channel i/p breaker is open and the channel under test is closed

6.3.4.Have the operator start the drive in turning gear.

6.3.5.Have the operator set the drive to run and accelerate the fan through the speed range.

6.3.6.The speed, field current, and the motor current should show no instability.

6.3.7.If the operation of the motor and load is satisfactory at all speeds, have the operator set the drive to off.

6.3.8.Repeat this test on the other channel.

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7. DUAL CHANNEL NO LOAD TESTS

7.1. Stop/Start Tests

7.1.1.Local Operation Channel 1

- Run Channel 1 Channel in Local.
- Initiate a Local Stop on the Channel 2 and ensure that nothing happens.
- Initiate a Channel 1 Local Stop and ensure that Channel 1 **ramps** down to stop.
- Re-start Channel 1 channel and initiate a Local Stop before the speed exceeds 5%. Ensure the drive trips and coast to rest immediately.

7.1.2.Local Operation Channel 2

- Run CHANNEL 2 Channel in Local.
- Initiate a Local Stop on the Channel 1 Channel and ensure that nothing happens.
- Initiate a Channel 2 Local Stop and ensure that Channel 2 **ramps** down to stop.
- Re-start Channel 2 channel and initiate a Local Stop before the speed exceeds 5%. Ensure the drive trips and coast to rest immediately.

7.1.3.Remote Operation 6-Pulse mode Channel 1

- Run Channel 1 remotely in 6-pulse mode. Leave Channel 2 in Local mode.
- Initiate a Local Stop on the Channel 2 and ensure that nothing happens.

7.1.4.Remote Operation 6-Pulse mode Channel 2

- Run Channel 2 Channel remotely in 6-pulse mode. Leave Channel 1 in Local mode.
- Initiate a Local Stop on the Channel 1 Channel and ensure that nothing happens.

This concludes the Start/Stop tests.

7.2. Operational & Stability Checks

7.2.1.Ensure that the dampers are closed.
7.2.2.Establish main drive power. Channel 1 controller is set as a master controller by default from the customer i/o board and the Channel 2 controller as the slave in a normal condition.
7.2.3.Set speed reference to minimum speed if it is not already preset.
7.2.4.Have the operator start the drive in turning gear.
7.2.5.Have the operator set the drive to run.
7.2.6.Increase the Speed Reference to 40%, 60%, 80% and record AC field Volts and Amps at each increment. Check the motor Volts, Amps, DC link current, and the Speed at each increment should be showing no instability.
7.2.7.If the operation of the drive is satisfactory at this point, gradually bring the motor up to maximum speed and test the motor at top speed. Run the drive for 1 hour. Monitor the speed, motor volts, motor current, and DC Reactor temperature and ensure that there are no abnormalities. Additionally, make a visual inspection of the thyristors LED's every hour.
7.2.8.Have the operator set the drive to run minimum speed.
7.2.9.Have the operator set the drive to run maximum.

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7.2.10.Set the speed reference to maximum speed, set the Local/Remote selector to the Remote mode, and press the MC start button. The motor should accelerate to maximum speed. Give the drive a 20% speed reference, and when the drive reaches about 30% speed, raise the reference back up to 100%. Press the Stop button to finish the testing. Press the Stop button to stop the drive system.
7.2.11.Stop the motor.

8. DUAL CHANNEL LOAD TEST

8.1. Full Load Current Checks

8.1.1.Ensure that a draught through the boiler is permissive and of great enough volume so as to be able to draw full load from the drive. Set:

M2.3 = 0	FORCE LOCAL MODE
M2.5 = 0	FORCE LOCAL START
M4 = 20%	LOCAL TEST SPEED REFERENCE

8.1.2.Ensure all the drive ready to run conditions are satisfied.
8.1.3.Establish main drive power.
8.1.4.Set speed reference to minimum speed if it is not already preset.
8.1.5.Start the drive. Ensure field excitation is on. Check that the converter gate indicating healthy status.
8.1.6.The speed control will have to be regulated from the control room, alternatively if another arrangement can be made to regulate the boiler pressure, the speed reference can be set locally.
8.1.7.Increase the Speed Reference to 40%, 60%, 80% and record AC field Volts and Amps at each increment. Check the motor Volts, Amps, DC link current, and the Speed at each increment should be showing no instability.
8.1.8.If the operation of the drive is satisfactory at this point, gradually bring the motor up to maximum speed and test the motor at top speed. Run the drive for 3 hours. Monitor the speed, motor volts, motor current, and DC Reactor temperature and ensure that there are no abnormalities. Additionally, make a visual inspection of the Thyristors LED's every hour.

Time	Speed	Motor Volts	Motor Current	DC Reactor Temp.
30 min				
60 min				
90 min				
120 min				
150 min				
180 min				

8.1.9.At this point the exciter phase rotation can be verified if it previously was uncertain.
8.1.10.Stop the motor.
8.1.11.With the remote reference set to 100% speed, set the drive to remote mode, and select run. The motor should accelerate to maximum speed. Give the drive a 20% speed reference, and when the drive reaches about 30% speed, raise the reference back up to 100%. Press the Stop button to finish the testing. Press the Stop button to stop the drive system.

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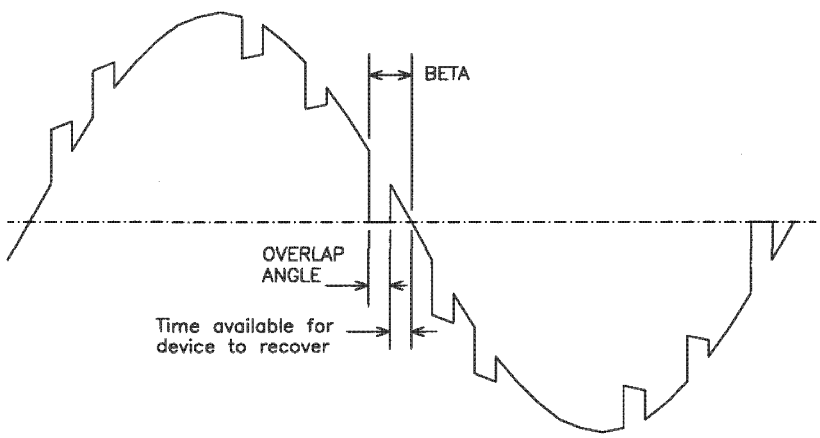
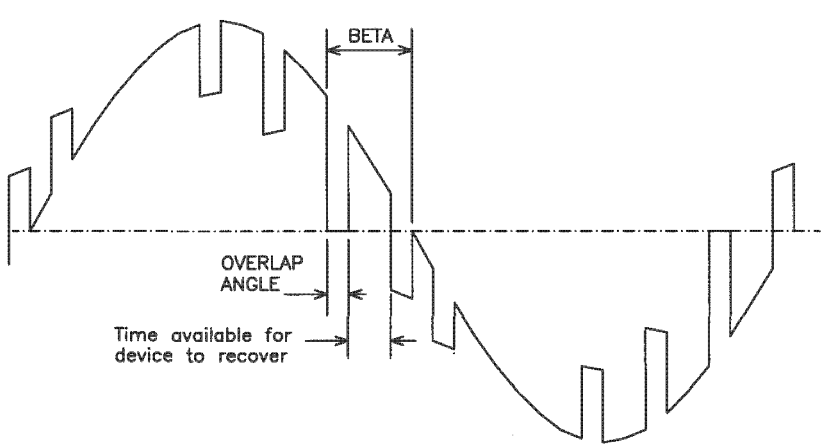
8.2. Beta and recovery time checks

At this stage the motor should be coupled to the load in order that rated load may be applied to the drive. With reference to the figure below, measurements and recordings of beta, overlap angle and time available for recovery must be made.

WHEN BETA IS LESS THAN 30 DEGREES:



WHEN BETA IS GREATER THAN 30 DEGREES:



Stator Voltage Feedback Waveform

Monitor the stator voltage feedback waveform at the input to the passive integrator board (if used) or the Type C I/O board as applicable.

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Run the drive at maximum speed, no load (if possible), and gradually increase the load up to the drive rating. Continuously monitor the time available for machine bridge devices to recover during this process.

At light load compare the measured beta angle in degrees with the beta angle in table L12615 (beta reference). This should give:

L12615 = measured beta ± 1°

Care must be taken when making this measurement. The oscilloscope time base should first be set to display a full cycle of the machine voltage waveform to confirm the frequency. The time base should then be altered to display a quarter cycle or less, including a commutation notch and a zero crossing.

If L12615 is outside the above tolerance the Project Engineer should be contacted for further advice.

As the load is increased, and the overlap angle increases, then:

$$\text{L12615} \approx \text{measured beta angle} - \frac{\text{overlap angle}}{2}$$

This is the anticipated effect of increasing load and is the reason that the measured beta angle and L12615 should be compared at light load.

Measure the true RMS motor line current on the three phases independently of the SIGMA using Rogowski coils and an accurate DVM.

Check that the time available for the machine bridge devices to recover is never less than the time given on the drive data sheet.

8.3. Drive operation

At rated speed and load, record the following information as a record of drive operation:

- Speed (L2152),
- Measured Beta,
- Overlap angle,
- Recovery time available,
- Current reference (L12601)
- True RMS motor line to line voltage,
- True RMS motor line current,
- Supply system load.

9. MISCELANEOUS DYNAMIC TESTS

9.1. Emergency Stop

9.1.1.If this has not been satisfactorily tested, run the drive in dual channel and prove each e-stop again.

9.2. Master / Slave controller switch over test.

9.2.1.In remote mode, run the drive to 20% speed.

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9.2.2.Initiate an exciter fault and ensure that, the Dual Channel Master becomes the 12 Pulse Slave and the 12 Pulse Slave becomes the 12 Pulse Master. Repeat for a chop over to the other channel.
9.2.3.Initiate a trip on the master channel. When tripping, the master channel will also trip its own output breaker. After a three second delay, the slave drive will chop over to master automatically.
9.2.4.Check the motor Volts and Amps, Field Volts and Amps, the motor Speed should be showing no instability.
9.2.5.Restart the tripped drive.
9.2.6.Initiate a trip on the master channel. When tripping, the master channel will also trip the output breaker. After a three second delay, the slave drive will chop over to master drive automatically.
9.2.7.Check the motor Volts and Amps, Field Volts and Amps, the motor Speed should be showing no instability.
9.2.8.Restart the tripped drive.
9.2.9.Repeat Steps 9.3.1 through 9.3.8 at 50% speed and 100% speed.
9.2.10.Press the stop button to stop the drive system.

10. FINAL PROCEDURES

10.1.1.Delete the Sigma memory by removing the back-up batteries and powering the sigma down. Power the Sigma back up and download the normal program to the regulator.
10.1.2.Make two diskette copies of the final "as tested" user program, including the ladder program (*.GLP) and links program (*.GDM). Personally deliver one copy to the contract engineer and one to the Service Manager. **This step is critical as the complied user program loaded into the SIGMA can not be downloaded or edited. Without these copies of the program all changed made during testing will be lost.**
10.1.3.Ensure that all as-built and as-tested hardware changes are marked in red ink on the certified schematics. Return the marked up schematics, this test instruction and all supporting documentation to the job folder.

APPENDIX 1 DRIVE COMMISSIONING CHECKLIST

DRIVE TITLE :_____

DRIVE REFERENCE :_____

DRIVE SERIAL NUMBER :_____

REF	TEST	CHECKED	REMARKS/READINGS	OTHERS
	Preparation			
2.1	General equipment check			
2.2	Interconnections			
2.3	Preliminary check with power off			
2.4	Low voltage supply check			
3.1	Power up regulator / gating power supply			
3.2	Download software			

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3.3	Digital I/O relay logic check			
3.4	Analog I/O check			
3.5	Exciter Reference Checks			
3.6	Diagnostic serial link check			
3.7	Hardware over current check			
3.8	Supply breaker interlocks			
3.9	Cooling system fill & check			
3.10	Main ACCB fast phase back timing check			
3.11	Firing pulse check			
4.1	Phasing checks			
4.2	DC link open circuit tests			
4.3	Open Loop Short Circuit Tests			
4.4	Closed Loop Short Circuit Tests			
4.5	Encoder Switching sequence Tests			
5.1	Single channel uncoupled safety inspection			
5.2	Mode 1 checks			
5.3	Stator volts feedback phasing and encoder alignment check			
5.4	Speed regulator control check			
6.1	Single channel load test-preliminary checks			
6.2	V/f control checks			
6.3	Single channel load tests Remote mode			
7.1	Dual channel no load operational & stability checks			
7.2	Stop/Start Tests			
8.1	Dual channel Full Load Current Checks			
9.1	Emergency Run Back Checks			

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9.2	Emergency Stop			
9.3	Chop over Checks			
10	Final Procedures & wrap-up			

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IGS 02-07 Circuit and Raceway Information					
Circuit Number	**Reserved in DataTrak**	From	To	Circuit Description	Notes
2CCEE122518	12/16/2003				
2CCEK260508	12/17/2003				
2CCEK2104C19	12/18/2003				
2CCEK2128B30	12/19/2003				
2CCEK2104C20	12/20/2003				

IP7014951

[redacted]

2CCE-K2128A.dwg	137 KB	AutoCAD Drawing	2/27/2004 2:39 PM
2CCE-K2128B.dwg	178 KB	AutoCAD Drawing	2/27/2004 2:21 PM
2CCE-K2134.dwg	135 KB	AutoCAD Drawing	3/1/2004 1:57 PM
2CCE-K2601.dwg	139 KB	AutoCAD Drawing	2/27/2004 2:20 PM
2CCE-K2605.dwg	105 KB	AutoCAD Drawing	2/27/2004 2:19 PM
2CCE-K2606A.dwg	152 KB	AutoCAD Drawing	2/27/2004 2:19 PM
2CCE-K2606B.dwg	152 KB	AutoCAD Drawing	2/27/2004 2:18 PM
2CCE-K2606C.dwg	173 KB	AutoCAD Drawing	2/27/2004 2:18 PM
2CCE-K2804A.dwg	209 KB	AutoCAD Drawing	3/1/2004 1:57 PM
2CCE-K2804B.dwg	143 KB	AutoCAD Drawing	3/1/2004 1:57 PM
2CCE-K2808A.dwg	188 KB	AutoCAD Drawing	2/27/2004 2:17 PM
2CCE-K2808B.dwg	223 KB	AutoCAD Drawing	3/22/2004 5:13 PM
2CCE-K2808B^ASFOUND^NRC.dwg	187 KB	AutoCAD Drawing	11/9/2004 11:13 AM
63.3601.05-90233_R001.dwg	26 KB	AutoCAD Drawing	4/21/2004 3:25 PM
63.3601.05-90256_R000.CIT	8,427 KB	Imagenation Document	2/19/2004 5:02 PM
BKR WIRING.dwg	51 KB	AutoCAD Drawing	3/10/2004 7:48 PM

IP7014953

U2 D ID Fan
Control Drawings Index 13 March 2004

Bernell,

Could you reserve drawings for me on the U2 flame scanner upgrade? Project # IGS02-07 wo 02-53663
Place the reserved drawings in directory:
N:\Current\Projects\IGS02\IGS02-07, ID Fan Drive Replacements\6.Documentation\Controls

* requires further updating

New Vendor drawings:

Modify Vendor dwgs:

Update drawings:
2CCE-K2104C SCHEMATIC DIAGRAM - INDUCED DRAFT FAN 1D WIRING

U2 D ID Fan drive upgrad controls parts list
Jerry Finlinson
2/3/2004
Use WO 02-53663

Req Date	estimated arrival	Req #	part	#	Each Price	Total
2/2/2004	2/13/2004	199468	Turck Bi3U-EM12-AP6X-H1141 inductive prox sensoı	8	76	608
2/2/2004	2/13/2004	199468	Turck RK4.4T-5 cord set, Euro-Fast quick disconnect	8	25.4	203.2
2/4/2004	2/16/2004	199795	Yokogawa 288 Thin edgewise panel meter	6	79	474

Process Technology, Inc., Salt Lake City
Process Technology, Inc., Salt Lake City

Weschler Inc. - PEP?

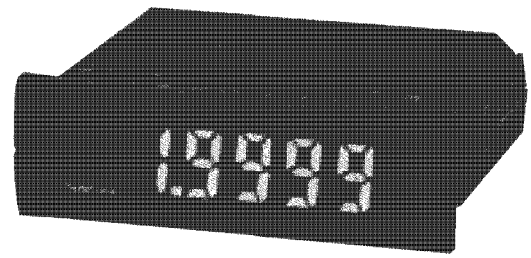
U2 ID FAN D IO				
Inputs	**Short Comment**	**From**		
10009	CS/PO & Stop 2CCE-K2104A			
10010	CS/Start & After Start 2CCE-K2104A			
10011	CS/After Stop or Start 2CCE-K2104A			
10012	PB/TRNGR 2CCE-K2104A			
10013	PB/RUN 2CCD-K2104A			
10025	1D1 FDR BRKR Open 2CCE - K2117A			
10026	CS/Close & After Close 2CCE - K2117A			
10027	CS/After Trip or Close 2CCE - K2117A			
10028	1D1 FDR BRKR Closed 2CCE - K2117A			
10029	Control Power OK 2CCE - K2117A			
10030	FD Fan 1A or 1B Running 2CCE - K2117A			
10031	FD Fan 1A or 1B In SVCE 2CCE - K2117A			
10041	Damper Opening 2CCE - K2308A			
10042	Damper Closing 2CCE - K2308A			
10045	1D2 FDR BRKR Open 2CCE - K2118A			
10046	CS/Close & After Close 2CCE - K2118A			
10047	CS/After Trip or Close 2CCE - K2118A			
10048	1D2 FDR BRKR Closed 2CCE - K2118A			
10060	Control Power OK 2CCE - K2118A			
10069	Gas Path Proven 2CCE - K2104A			
10070	Furnace Press Low 2CCE - K2104A			
10093	Run Memory 2CCE - K2104A			
10137	In ISLN DMPR OPEN CDR-88 2CCE - K2304A			
10145	Lube Oil Press Low 2CCE - K2324B			
10146	LSS/RUN 2CCE - K2324B			
10147	LSS/STBY 2CCE - K2324B			
10148	LSS/STOP 2CCE - K2324B			
10149	LSS/START 2CCE - K2316A			
10150	LSS/STOP 2CCE - K2316A			
10151	DMPR Seal Air Fan Running 2CCE - K2316A			
10152	DMPR Seal Air Fan Stopped 2CCE - K2316A			
10153	DAMPER OPEN 2CCE - K2308A			
10154	DAMPER CLOSED 2CCE - K2308A			
10161	Valve Opening 2CCE - K2320A			
10162	Valve Closing 2CCE - K2320A			
10163	Valve Closed 2CCE - K2320A			
10164	Valve Open 2CCE - K2320A			
10167	Control Power OK 2CCE - K2324A			
10168	Lube Oil Pump Running 2CCE - K2324A			

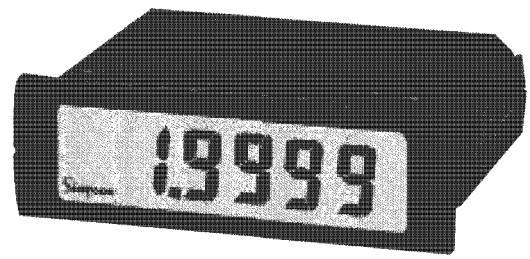
10169	Lube Oil Press Low 2CCE - K2324A			
10170	LSS/RUN 2CCE - K2324A			
10171	LSS/STBY 2CCE - K2324A			
10172	LSS/STOP 2CCE - K2324A			
10177	MCC BRKR CLOSED OR TRIPPED 2CCE - K2320A			
10178	AIRI FILTER D/P HIGH 2CCE - K2104A			
10179	XFMR 1D1 TEMP H-H 2CCE - K2104A			
10180	XFMR 1D2 TEMP H-H 2CCE - K2104A			
10183	CONTROL POWER OK 2CCE - K2324B			
10184	LUBE OIL PUMP RUNNING 2CCE - K2324B			
10193	LUBE OIL PRESS ADEQUATE 2CCE - K2324C			
10194	LUBE OIL PRESS LOW 2CCE - K2324C			
10195	LUBE OIL PRESS LOW 2CCE - K2324C			
10196	LUBE OIL FILTER D/P HIGH 2CCE - K2324C			
10197	LUBE OIL TEMP HIGH 2CCE - K2324C			
10198	LUBE OIL TEMP HIGH 2CCE - K2324C			
10199	LUBE OIL TEMP LOW 2CCE - K2324C			
10200	LUBE OIL LEVEL LOW 2CCE - K2324C			
10211	ID FAN IN SERVICE 2CCE - K2308A			
10212	ID FAN RUNNING 2CCE - K2308A			
10225	MOTOR AT TRNGR SPEED 2CCE - K2128A			
10226	MOTOR ABOVE MIN 150 RPM 2CCE - K2128A			
10227	MOTOR AT ZERO SPEED 2CCE - K2128A			
10228	VARIABLE SP DR 1D2 TROUBLE 2CCE - K2606A			
10229	VARIABLE SP DR 1D1 TROUBLE 2CCE - K2606A			
10230	CONTROL POWER OK 2CCE - K2104A			
10231	MOTOR TURNING 2CCE - K2128A			
10232	TRIP COMMAND 2CCE - K2128A			
10233	CNTOR 1D2 OPEN 2CCE - K2104A			
10234	CNTOR 1D2 CLOSED 2CCE - K2104A			
10235	CNTOR 1D1 OPEN 2CCE - K2104A			
10236	CNTOR 1D1 CLOSED 2CCE - K2104A			
10241	CONTROL DMPR OPEN CDR-96 2CCE - K2312			
10242	CONTROL DMPR CLOSED CDR-96 2CCE - K2312			
10243	MOTOR TURNING 2CCE - K2127A			
10244	TRIP COMMAND 2CCE - K2127A			

DC Current

Mini-Max M245 Series Digital Panel Meter

- ***Minimum Depth Indicator - Less Than 2.5" (60mm) of Space Required Behind the Panel***
- ***Stackable Mounting Bracket Included for Easy Installation***
- ***4-1/2 Digit, 0.5" (12.7mm) High LCD Display with Optional Negative Image, Bright Red Backlighting***
- ***Broad Range Display Scaling***
- ***Standard Screw Terminals for Easy Installation***
- ***Six Current Ranges: 200µA, 2mA, 20mA, 200mA, 2A, 5A***
- ***85-250VAC or 9-32VDC Power Supply***

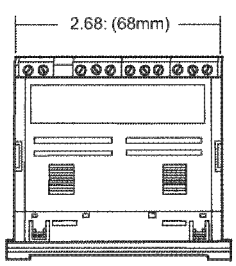


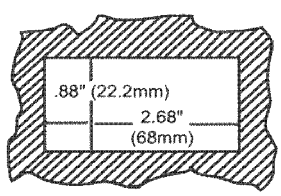


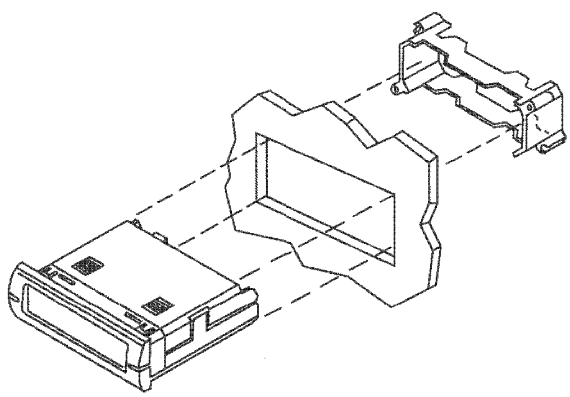
Simpson's Mini-Max Current Indicators provide high quality, accuracy and reliability in a compact, 60mm deep case. Units offer 4-1/2 digit, 0.5" (12.7mm) LCD display and are available with a bright red, negative image backlight option. All units feature user-selectable decimal point, auto zero and scaling capabilities.

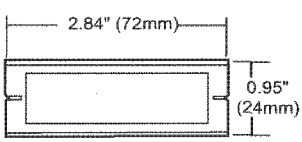
A unique mounting bracket is provided to allow for vertical or horizontal stacking of multiple indicators. All Mini-Max units feature a 3/64 DIN, high-impact plastic case. The standard units have a clear viewing window, and the units with optional negative image, red backlighting have a red window.

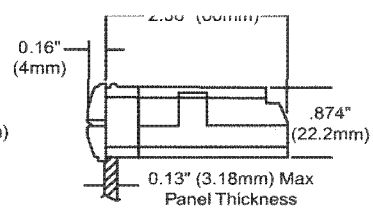
Installation and Panel Cutout











Mounting Requirements

Insert the Mini-Max through the panel, and then slide the mounting bracket on to the Mini-Max. The mounting bracket allows Mini-Max units to be stacked side-to-side or top-to-bottom and maintain the DIN standard panel arrangements in 24mm by 72mm multiples. Panel cutout instructions for stacking multiple units are provided under "Stacking Features."

Specifications

DISPLAY
Type: 7-segment LCD
Height: 0.5" (12.7mm)
Decimal point: 3-position programmable
Overrange indication: Most significant digit = "1"
Backlighting: Optional negative image, red LED backlighting
Polarity: Auto with "-" indication, "+" implied

POWER REQUIREMENTS
AC Volt: 85-250VAC @40-440Hz
DC Volt: 9-32VDC
Power Consumption:
85-250VAC: 2.5VA min/4VA max
9-32VDC: 1.5VA min/3VA max

Rated Circuit to Ground Voltage: 750Vrms

ACCURACY @ 25°C
±(0.04% of reading + 1 count)
2A: ±(0.25% of reading + 1 count
5A: ±(0.5% of reading + 1 count)

ENVIRONMENTAL
Operating Temperature: 0 to 55°C
Storage Temperature: -10 to 60°C
Relative Humidity: 0 to 85% non condensing @ 40°C
Temperature Coefficient:
(± 0.02% of input ± 0.2 digits) / °C
Warmup time: Less than 20 minutes

NOISE REJECTION
NMRR: 60dB, 50/60Hz
CMRR: (w/1KΩ unbalanced @ 60Hz): 90dB min

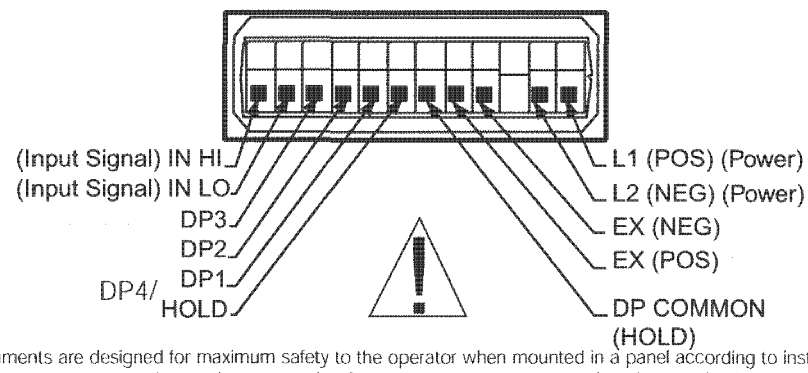
ANALOG TO DIGITAL CONVERSION
Technique: Integrating
Rate: 3 samples/second-typical

MECHANICAL
Bezel: 0.95" x 2.84" (24mm x 72mm)
Depth: 2.36" (60mm)
Panel cutout: 0.88" x 2.68" (22.2mm x 68mm)
Weight: 3.5oz (99.2g)
Case Material:
94-0,UL-rated, glass-filled thermoplastic

INPUTS: DC Current

Range	Resolution	Voltage Drop	Max. Input (unfused)
200µA	10µA	200mV	10mA
2mA	100µA	200mV	40mA
20mA	1µA	200mV	100mA
200mA	10µA	200mV	400mA
2A	100µA	200mV	3A
5A	1mA	50mV	6A

Wiring Display



These instruments are designed for maximum safety to the operator when mounted in a panel according to instructions. They are not to be used unmounted or for exploratory measurements in unknown circuits.

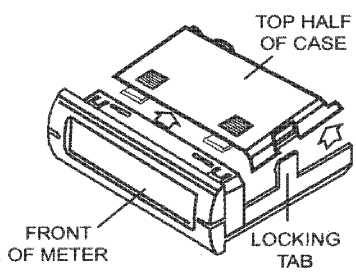
Decimal Point: To select a decimal point, connect the appropriate DP pin (DP1, DP2, DP3 or DP4) to the DP COMMON (HOLD). Unused DP inputs may remain unconnected (open).

Display Hold: Connect HOLD to DP COMMON (HOLD). If this feature is not required, the DP COMMON (HOLD) pin may remain unconnected (open). Hold is optional on this model, and when equipped, replaces DP4. This feature is available from our modification centers.

Input Signal: Connect the IN HI and IN LO to the signal to be monitored.

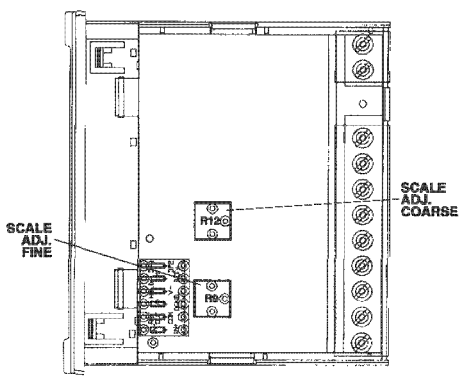
Input Power: Connect power to the L1 and L2 terminals. For AC powered units, L1 and L2 are not polarized.
For 9-32 DC powered units, L1 must be positive with respect to L2.

Display Scaling



Using a screwdriver or thumbnail, spread tab on each side of case to unlock top half. Lift rear top half and slide away from front of meter.

Mini-Max indicators have broad range coarse and fine adjustments for display scaling. There are no optional connections required for these to function. The "coarse" calibration R12 will allow a broad range of scaling values. The meter can be scaled down to 1/2 the value of the input. The "fine" calibration R9 allows for an approximate range of 1% of the "coarse" calibration. Apply full scale input to the meter. Adjust R12 to be within 1% of the desired scaled value, then use R9 to obtain the final desired result.

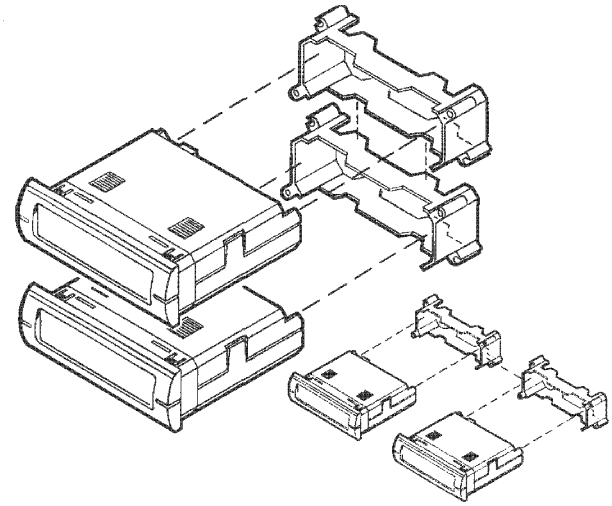


Stacking Features

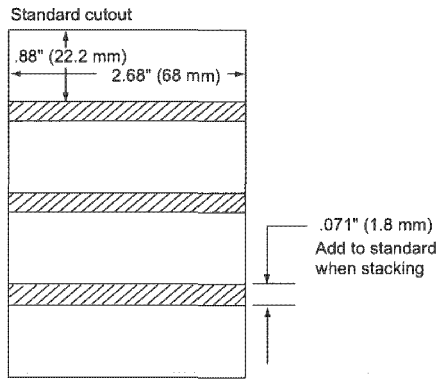
The mounting brackets, included with every Mini-Max, can be connected together. Multiple units can be mounted in a single opening, allowing perfect alignment.

To punch one hole for multiple units, be sure to adjust the standard panel cutout dimensions as shown here; otherwise the meters will not fit properly in the hole.

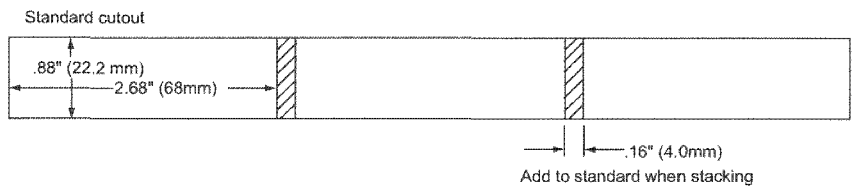
Mounting multiple units is quick and easy. Install the first meter (bottom unit first if stacking vertically). Position the next mounting bracket snugly against the first one, and slide the second meter into place. Repeat for remaining units.



Vertical



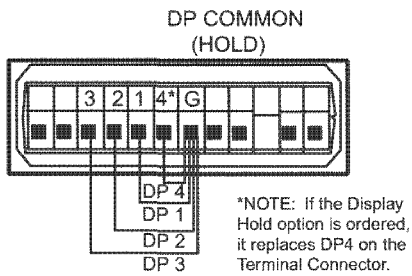
Horizontal

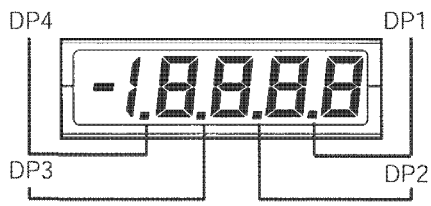


Backlight Option and Decimal Point Selection

Negative image, bright red backlighting is available in the Mini-Max. This illumination allows the unit to be read in low light areas. Backlighting power is supplied by the Mini-Max, so no additional external power is required.

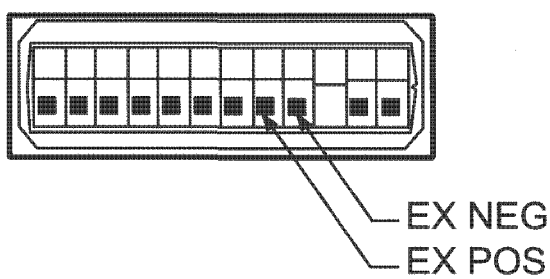
Decimal point selection is accomplished by connecting the appropriate DP terminal to the DP Common terminal.





Excitation Output

Excitation output is available in the Mini-Max for powering external transmitters or transducers. Excitation is available from the EX POS and EX NEG terminals. This source is isolated from the measurement input as well as the input power circuits. The voltages available are 12VDC or 24VDC, with a maximum load current of 25 milliamps. This feature eliminates the need to mount an external DC power source for transducers or sensors used in your application.



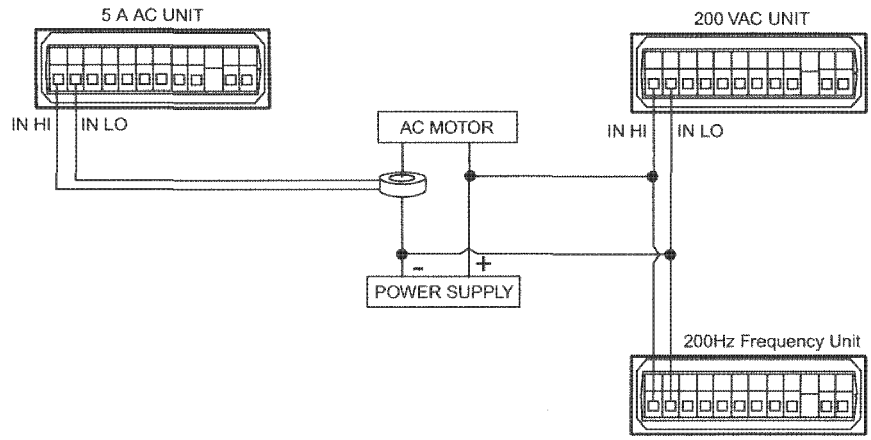
Do not exceed an excitation load current of 25mA!

Application Example

A company needs to monitor the power supply voltage and load current of a 12VDC motor.

Voltage: A Mini-Max DC Volt meter, configured for the 20 volt range, is installed in parallel with the power source. The IN HI is connected to the positive lead of the power supply. The IN LO is connected to the negative lead of the power supply.

Current: A second Mini-Max DC Volt meter, configured for the 200 millivolt range, is used with a 100A/50mV shunt (sold separately) to measure the load current. The meter is first scaled to read 100.0 at 50mV by applying a 50mV input to the meter and adjusting R9 and R12 until the display reads 100.0. The meter is connected to the shunt, and the shunt is installed in series on the negative leg of the power supply. The positive lead of the shunt is connected to the IN HI terminal, and the negative lead connected to the IN LO terminal. The Mini-Max units will indicate the power supply voltage and load current of the motor.



Ordering Information

The Mini Max Voltage Indicator can be configured by making an entry for each box

Basic Unit — M245 4-1/2 Digit Indicator

Display — 0 Non Backlight; 1 Negative Image Red

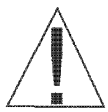
DPM Power Supply — 0 85-250VAC; 2 9-32VDC

Range — 21 200uA; 22 2mA; 23 20mA; 24 200mA; 25 2A; 26 5A

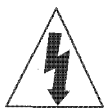
Excitation Output — 0 None; 1 12VDC; 2 24VDC; 25 DCmA max output

NOTE: Display hold feature is configured at the factory only. Must specify at time of order.

Safety Symbols



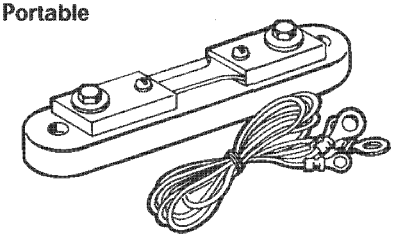
The WARNING sign denotes a hazard. It calls attention to a procedure, practice, or the like, which, if not correctly performed or adhered to, could result in personal injury.



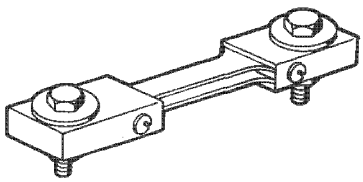
The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly adhered to, could result in damage to or destruction of part or all of the instrument.

Accessories

Portable



Switchboard



External shunts enable digital panel meters to indicate higher currents than can be provided with self-contained internal shunt meters. The shunt is installed in series with the load and source. The shunts produce a DCmV drop which is sent to the display unit. The Mini-Max can be scaled to display the actual current between the load and the source. Simpson manufactures portable and switchboard shunts.

Each shunt includes 5' leads.

Ordering Information

Portable Shunts 50mV

Amps	Cat. Number
1	06700
5	06703
10	06704
15	06705
25	06707
30	06708
50	06709
75	06711
100	06713
150	06714
200	06715

Switchboard Shunts 50mV

Amps	Cat. Number
100	06500
150	06503
200	06504
250	06505
300	06506
400	06507
500	06508

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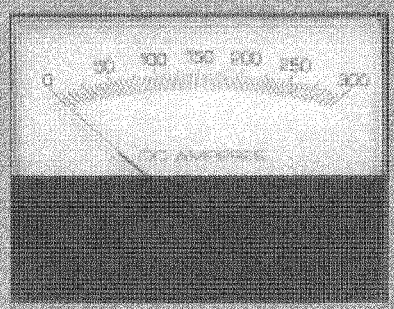
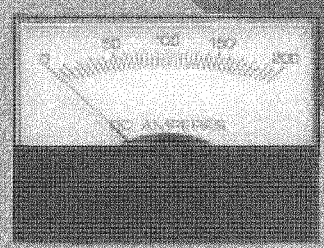
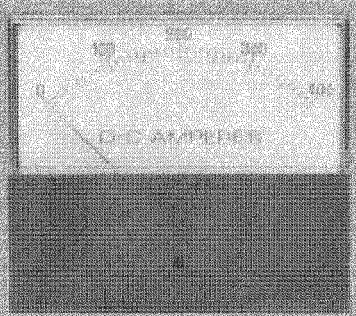
IP7014962

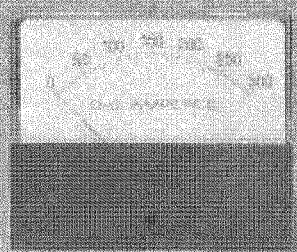
PANEL METERS

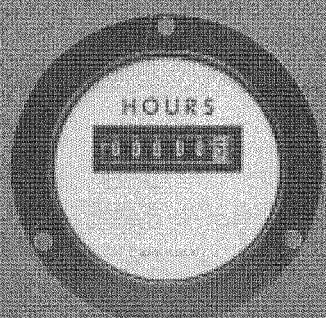


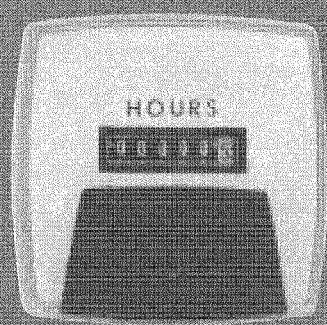


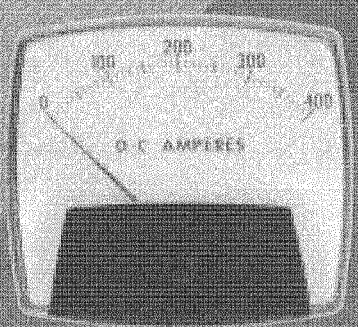
YOKOGAWA

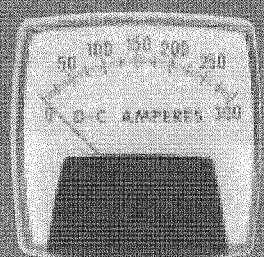












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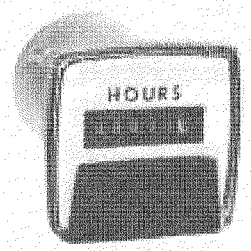
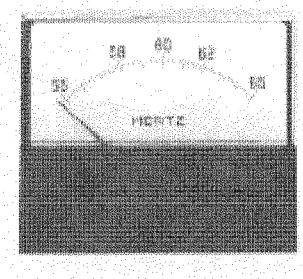


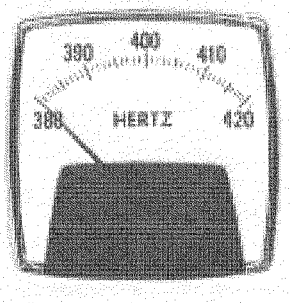
Elapsed Time Meters

Devices will match the frequency of AC power systems. Six-digit counters record hours, tenths of hours, minutes and tenths of minutes. Reset or non-reset models available.



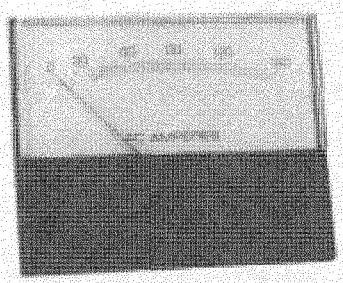
Horizon Line Panel Meters

These meters possess the same precision qualities as New Big Look. In addition, Horizon Line panel meters can be front or rear mounted on panel.



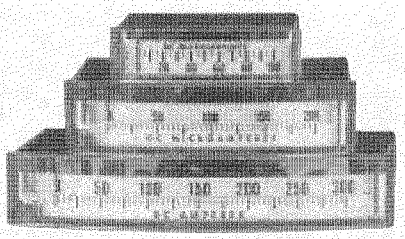
New Big Look Panel Meters

These meters feature extra-wide scales, big bold numerals above the scale and divisions for unobstructed reading. Tapered needle-sharp pointers and shadow-free acrylic covers help to pinpoint values. Available in taut band and pivot and jewel types. Gasket sealer gives New Big Look dust and moisture resistant design. (Except 1½").



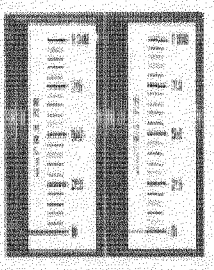
Stylist Series Panel Meters

Available in Window mount or Surface mount styles. Optional bezels for Surface mount permit rear panel mounting. Standard movement torque to weight ratio is approximately 4 times greater than most other manufacturer's high torque versions.



Thin edgewise meters

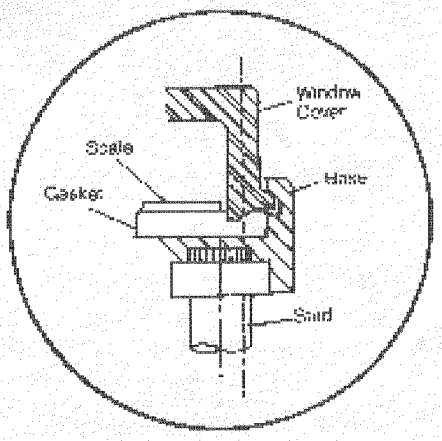
Our thin element design provides the maximum performance in the smallest of spaces. Available in 1½" to 3½" sizes for vertical or horizontal mounting.



Edgewise Meters

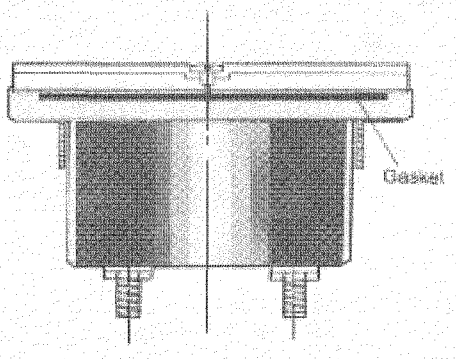
YOKOGAWA's answer to the squeeze for space problem. This design allows meters to be mounted vertically or horizontally. They can stand alone or be stacked in space-saving clusters. Built-in magnetic shielding prevents interference among meters and removes the burden of special calibration.

YOKOGAWA Offers These Advantages . . .



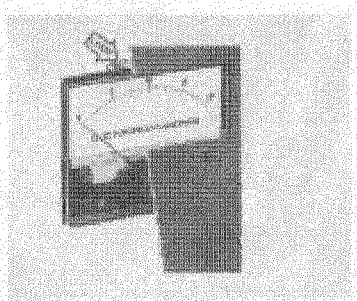
Gasket Sealing Design Establishes A New Industry Standard

Dust resistant construction is now a standard feature of all New Big Look panel meters 2½"-4½" only. YOKOGAWA's unique gasket sealing design eliminates the need for a crimped bezel, providing for quick modification and scale changes while maintaining the integrity of the meters.



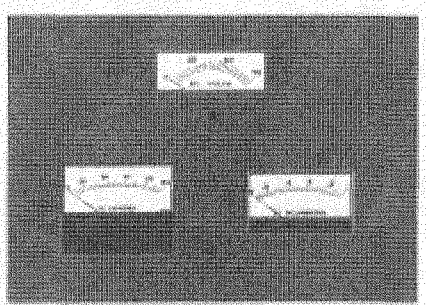
Dust Resistant Construction

YOKOGAWA Big Look panel meters, except 11/2", feature gasketed construction to seal out dust and other air-suspended damaging particles. Application is ideal for adverse environments. Special dust resistant features are included on all YOKOGAWA New Big Look meters, (except 1½"). For more severe applications, to meet UL-1437 or IEC 144 requirements, other models are also available upon request.



Back-Of-Panel Mounting For Horizon Line

Horizon Line panel meters can be mounted either behind or in front of the panel. Behind-panel mounting is easy . . . just remove snap-off mask and mount. No special mounting hardware or bezel is required. This design feature improves panel appearance . . . saves time and money. When illuminated scales are required, simply position light source as shown, or in any suitable position along the edge of the instrument.

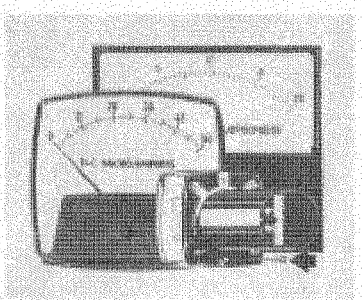


Three Mounting Types Available in Stylist Series

Rear Panel Window Mount

Front of Panel Surface Mount

Rear Panel Surface Mount Available with Optional Bezel



Clean, Readable Case Design Provides Extra Safety

YOKOGAWA's brand New Big Look and Horizon Line panel meters are designed to provide attractive styling, quick, sure readability for any application . . . and a built in safety feature to help you meet national safety requirements. If you must remove the acrylic cover, you have to remove the instrument itself from the panel in order to reach the special safety screws holding on the cover. Removing the meter prevents shock hazard. This safety feature is standard on all New Big Look and Horizon Line meters.

New Big Look, Horizon Line and Stylist Panel Meters

Suspension

Taut Band

Taut band is a means of suspending the moving mechanism between two ribbons of metal, obviating the need for pivots, jewels and control springs found in conventional mechanisms. The absence of friction resulting from this permits greater sensitivities and provides more rugged meters. Common failures of conventional meters subjected to shock testing are cracked jewels and/or blunted pivots. Taut band, without pivot and jewels, consequently, will withstand shock in excess of that specified for pivot and jewel meters. For example, ANSI Specifications for panel meters require 50G shock. Taut-band meters will withstand 100G shock.

Pivot and Jewel

In this design the coil and pointer are supported by polished steel pivots at each end which fit into jewel bearings. Pivot and jewel meters are recommended for high-vibration environments because of the mechanism's inherent stability and strength. Accuracy and repeatability are almost equal to the taut-band's, and good performance from the pivot and jewel construction is the reason for its long popularity. Don't specify pivot and jewel meters for applications that involve high shock, but do take advantage of this meter's ability to withstand vibration.

High-sensitivity DC Voltmeters

Standard DC voltmeter sensitivity is 1000 ohms/volt. Expressed differently, 1000 ohms/volt sensitivity means that the meter draws approximately one milliamp full-scale current.

Occasionally lower current drains are necessary, hence higher sensitivities may be required. The table below compares available sensitivities, maximum self-contained voltages, and approximate full-scale currents. The voltage range could be extended by using external resistors.

Expanded-scale Voltmeters

For very close monitoring of voltages, Zener diode expanded scale voltmeters are available in 3½- and 4½-inch sizes for AC and DC ratings. Accuracy is ±0.5% of full-scale value. Standard voltage spans are listed in "Ratings."

Expanded scale voltmeters can be furnished for any mid-span values from 12 to 300 volts. Minimum span is 16% of mid-span value.

Frequency Effect — AC Meters

Iron vane voltmeters are sensitive to frequency and should not be used on frequencies other than design frequency. (Standard voltmeters are calibrated at 60 Hertz. Used at 50 Hertz, accuracy becomes ±2¼%. There are also 150- and 300-volt ratings listed which are calibrated at 400 Hertz). For calibrations at frequencies other than 60 and 400 Hertz, refer to factory.

All Iron-vane ammeters (which produce a conventional scale distribution with divisions crowded in lower third of scale) from 10 milliamperes to 50 amperes are virtually unaffected by a change in frequency; e.g., a stock ammeter (calibrated at 60 Hertz) when used at 400 Hertz incurs an additional error of only .5 percent full-scale. If used on 1000 Hertz, the additional error is 4 percent. We recommend use of stock (60 Hertz) ammeters on any frequency in the range of 25 Hertz to 400 Hertz. For calibration at frequencies outside the 25-Hertz to 400-Hertz range, refer to factory or use a rectifier-type AC ammeter.

Rectifier-type Meters

Rectifier-type meters differ from iron-vane mechanisms in that:

- They provide a nominally linear (DC) scale rather than conventional iron-vane distribution which has a slight crowding at low end of scale.
- AC current measurements of microamperes and milliamperes at minimum power consumption are permitted.
- AC voltmeters of higher sensitivity (ohms/volt) than iron-vane types can be made.
- Frequency response of rectifier type meters is essentially flat from 20 to 1,000 Hertz (1% effect from reference to 60 Hertz). Rectifier-type meters employ a full-wave rectifier and are available in ratings of 500μA to 30A.

Suppressed-zero DC Meters

DC meters can be mechanically suppressed up to 20% of end-scale value. However, additional errors are introduced by suppressions; e.g.,

Errors at 20% suppression = ±3% of end-scale

Many process transmitters in use today provide a 4-20mA signal (occasionally 10-50 mA or 1-5mA) and require a suppressed-zero meter with operating zero set. These are known as "live-zero" and are standard.

Higher Accuracy

Standard calibration accuracy is ±2% of full scale. DC meters can be calibrated to ±1% of full scale as a special model in 3½" and 4½" with mirrored scale.

Conduit Mounting Case — 2½-inch New Big Look Meter

Available only for 2½-inch Type 250 panel meters, for indoor or outdoor use, the conduit-mounted case provides protection to the meter under severe environmental conditions. The conduit case is both sealed and weatherproof and is pre-drilled, ready for mounting of separately ordered panel meters. Assembly of meter into case is done by purchaser. (Drawing No. 2579K10700.)

Data subject to change without notice.

Maximum and Minimum Ratings

In general, the maximum and minimum ratings of current and voltage are those listed in "Ratings." Listed are rating limits for self-contained meters.

Ratings greater than those listed can be accomplished by use of external shunts, resistors or transformers. Meters to be used with external accessories are shown in "Ratings." See page 29 for Shunts, resistors and Transformers.

MINIMUM RATING

SERIES	STYLIST				BIG LOOK & HORIZON LINE			
SIZE/RATING	1½	2½	3½	4½	1½	2½	3½	4½
DC CURRENT	10μA				20μA			50μA
DC VOLTAGE	50mV				50mV			
AC CURRENT (IRON VANE)	---	10mA			---	10mA		
AC VOLTAGE (IRON VANE)	---	3V			---	3V		
AC CURRENT (RECTIFIER)	1mA				500μA			
AC VOLTAGE (RECTIFIER)	3V				10V			

MAXIMUM RATING

DC CURRENT	10A	50A		15A	30A	50A
DC VOLTAGE	1000V			300V		600V
AC CURRENT (IRON VANE)	---	50A		---	30A	80A
AC VOLTAGE (IRON VANE)	---	600V		---	300V	600V
AC CURRENT (RECTIFIER)	100mA	30A		20mA		
AC VOLTAGE (RECTIFIER)	600V			150V		300V

Table of Contents

	New Big Look	Horizon Line	Stylist	Elapsed Time	185 Edgewise	280 Edgewise
DC Voltmeters	2-3	8	14		26	27
DC Ammeters	3-5	8-10	15-16		26	28
DC Microammeters	3	8-9	15		26	28
DC Milliammeters	4	9	15		26	28
AC Voltmeters	5-6	10-11	17		26	28
AC Ammeters	6-7	11-12	17-19			28
AC Microammeters	6	11			26	28
AC Milliammeters	6	12	17, 18		26	28
AC Frequency Meters	13	13	19			
AC Motor Load Indicators	12	12				
Expanded Scale Voltmeters	3,5	8, 11	14, 17			
Elapsed Time Meters				24-25		
Terminal Resistance Values	20-21	20-21	22-23		26	27-28
Cross Reference to Other Manufacturers	32	32	32			
Electrical and Physical Options	30-31	30-31	30-31		30-31	30-31
Parts & Accessories	29	29	29		25, 29	27, 29
Dimensional Drawings	32-33	34-35	36	38, 39	37	38

Key to 200-Prefix Catalog Numbers

250 2 40 LS LS 7,8,9,1 XXX or XXXXXXXXXX

Digits 1, 2, and 3
Style
250 - New Big Look (Taut Band), (I/V*-P&J)
251 - Horizon Line (Taut Band), (I/V*-P&J)
254 - New Big Look (P&J)
255 - Horizon Line (P&J)
260 - Surface Mount (Taut Band), (I/V*-P&J)
261 - Window Mount (Taut Band), (I/V*-P&J)
264 - (P&J) Surface Mount
265 - (P&J) Window Mount

Digit 4 - Size
1 - 1½"
2 - 2½"
3 - 3½"
4 - 4½"

Digits 5 and 6
Elec. and Mechanical Variables
00 - DC Amps Zero-Left
01 - DC Amps Zero-Center
04 - DC Volts/Ext. Res. Zero-Left
05 - DC Volts/Ext. Res. Zero-Center
10 - AC Amps Rectified
20 - DC Volts Zero-Left
21 - DC Volts Zero-Center
24 - DC Millivolts Zero-Left
25 - DC Millivolts Zero-Center
30 - AC Volts Rectified
37 - AC Expanded Scale Voltmeter
38 - DC Expanded Scale Voltmeter
40 - AC Amps (I/V)* 60 Hz
44 - AC Volts (I/V)* 60 Hz
45 - AC Volts 400 Hz (I/V)*
50 - Frequency

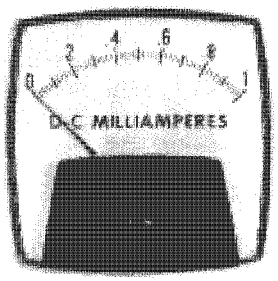
Digits 7 and 8 - Elec. Rating
Example:
LS = 5 Amps
MT = 10 Amps
NG = 20 Amps

Digits 9 and 10 - Scale
Example:
LS = 0-5 Amps
MT= 0-10 Amps
NG = 0-20 Amps

Digit 11 - Factory Style
For factory use.

Digits 12, 13, 14, 15, 16, 17-21Special Units
When used, these denote unique models. Refer to factory for details.

*I/V = Iron Vane Mechanism



Type 250 and 254
New Big Look

Specifications

Accuracy: All DC and AC iron-vane; ±2% of full-scale AC rectifier type; ±3% of full scale (with 60 Hz sine wave at 25° C). When standard 60 Hz iron vane ammeters are used at the extreme limits of 25 or 400 Hz, additional error (approx. .75%) may be experienced. Expanded-scale voltmeters: ±.5% of full scale value.

ANSI Specification: All meters meet ANSI Specifications C-39.1

Overload: Voltmeters (AC and DC) - 50% momentary, 20% sustained. Ammeters (AC and DC) momentary; 10 times the rated current for 10 consecutive intervals of .5 second with a 1 minute interval between successive applications; sustained: 20% for six hours.

Scale Data: 90 degree rotation.

Scale Length:

Size	New Big Look
1½"	1.40"
2½"	2.06"
3½"	2.88"
4½"	3.93"

Insulation Level: All meters (except 1½"), 2600 Vrms Hi-pot, 1½"-1500 Vrms Hi-pot.

Burden Data: AC ammeter-5 amps, 0.5 va, Max. 0.5 power-factor lagging @ 60 Hz. AC voltmeter - unity power factor.

Response Time and Overshoot: Response time: 3 seconds (max.) for 2½", 3½", 4½" size for microammeters; 2 seconds (max.) for all other DC ratings, and 2.5 seconds (max) for AC ratings. Maximum of 40% overshoot.

Dimensions: See page 32-33

How To Order

To order New Big Look panel meters use the appropriate catalog numbers provided in the tables. Taut band & AC I/V instruments have a 250 prefix number. Pivot & Jewel instruments have a prefix of 254.

Ordering Examples:

1. 2½", 300 V DC Voltmeter, zero left, taut band - 250 220 RXRX
2. 2½", 300 V DC Voltmeter, zero left, pivot & jewel, 254 style - 254 220 RXRX
3. 2½", 300 V AC (Iron Vane), pivot & jewel - 250244 RXRX

Notes:

Pivot & jewel instruments are not available in 1½" size.

Severe-duty meters are available to meet CSA, UL 1437 and IEC 144 requirements. **UL/CSA version, with flame retardant window and base, is not offered in 1½".** IEC version is not offered in 1½" and 4½". To order, add /CSA, /UL or IEC after catalog number, or contact factory.

For ratings and scales not listed contact factory.

DC Voltmeters

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC VOLTMETERS — ZERO-LEFT							
1.0 Volts	250 120 LALA	250 220 LALA	254 220 LALA	250 320 LALA	254 320 LALA	250 420 LALA	254 420 LALA
1.5 Volts	250 120 LCLC	250 220 LCLC	254 220 LCLC	250 320 LCLC	254 320 LCLC	250 420 LCLC	254 420 LCLC
3 Volts	250 120 LJLJ	250 220 LJLJ	254 220 LJLJ	250 320 LJLJ	254 320 LJLJ	250 420 LJLJ	254 420 LJLJ
5 Volts	250 120 LSLS	250 220 LSLS	254 220 LSLS	250 320 LSLS	254 320 LSLS	250 420 LSLS	254 420 LSLS
8 Volts	250 120 MJMJ	250 220 MJMJ	254 220 MJMJ	250 320 MJMJ	254 320 MJMJ	250 420 MJMJ	254 420 MJMJ
10 Volts	250 120 MTMT	250 220 MTMT	254 220 MTMT	250 320 MTMT	254 320 MTMT	250 420 MTMT	254 420 MTMT
15 Volts	250 120 NDND	250 220 NDND	254 220 NDND	250 320 NDND	254 320 NDND	250 420 NDND	254 420 NDND
30 Volts	250 120 NLNL	250 220 NLNL	254 220 NLNL	250 320 NLNL	254 320 NLNL	250 420 NLNL	254 420 NLNL
40 Volts	250 120 NPNP	250 220 NPNP	.....	250 320 NPNP	.....	250 420 NPNP	.....
50 Volts	250 120 NTNT	250 220 NTNT	254 220 NTNT	250 320 NTNT	254 320 NTNT	250 420 NTNT	254 420 NTNT
80 Volts	250 120 PDPD	250 220 PDPD	254 220 PDPD	250 320 PDPD	254 320 PDPD	250 420 PDPD	254 420 PDPD
100 Volts	250 120 PKPK	250 220 PKPK	254 220 PKPK	250 320 PKPK	254 320 PKPK	250 420 PKPK	254 420 PKPK
150 Volts	250 120 PZPZ	250 220 PZPZ	254 220 PZPZ	250 320 PZPZ	254 320 PZPZ	250 420 PZPZ	254 420 PZPZ
200 Volts	250 120 RLRL	250 220 RLRL	254 220 RLRL	250 320 RLRL	254 320 RLRL	250 420 RLRL	254 420 RLRL
250 Volts	250 120 RSRS	250 220 RSRS	254 220 RSRS	250 320 RSRS	254 320 RSRS	250 420 RSRS	254 420 RSRS
300 Volts	250 120 RXRX	250 220 RXRX	254 220 RXRX	250 320 RXRX	254 320 RXRX	250 420 RXRX	254 420 RXRX
500 Volts	.....	.....	.....	250 320 SFSF	254 320 SFSF	250 420 SFSF	254 420 SFSF
600 Volts	.....	.....	.....	250 320 SJSJ	254 320 SJSJ	250 420 SJSJ	254 420 SJSJD
DC VOLTMETERS — ZERO-LEFT, RATED 0-1 mA DC, FOR USE WITH EXTERNAL RESISTORS. RESISTORS NOT INCLUDED (SEE PAGE 29 FOR RESISTORS)							
SCALE ONLY							
500 Volts	250 104 FASF	250 204 FASF	254 204 FASF	.....	.....	.....	.....
600 Volts	250 104 FASJ	250 204 FASJ	254 204 FASJ	.....	.....	.....	.....
750 Volts	250 104 FASM	250 204 FASM	254 204 FASM	250 304 FASM	254 304 FASM	250 404 FASM	254 404 FASM

IP7014968

DC Voltmeters Cont'd

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC VOLTMETERS — ZERO-CENTER							
5-0-5 Volts	250 121 LSLS	250 221 LSLS	254 221 LSLS	250 321 LSLS	254 321 LSLS	250 421 LSLS	254 421 LSLS
10-0-10 Volts	250 121 MTMT	250 221 MTMT	254 221 MTMT	250 321 MTMT	254 321 MTMT	250 421 MTMT	254 421 MTMT
30-0-30 Volts	250 121 NLNL	250 221 NLNL	254 221 NLNL	250 321 NLNL	254 321 NLNL	250 421 NLNL	254 421 NLNL
50-0-50 Volts	250 121 NTNT	250 221 NTNT	254 221 NTNT	250 321 NTNT	254 321 NTNT	250 421 NTNT	254 421 NTNT
80-0-80 Volts	250 121 PDPD	250 221 PDPD	254 221 PDPD	250 321 PDPD	254 321 PDPD	250 421 PDPD	254 421 PDPD
150-0-150 Volts	250 121 PZPZ	250 221 PZPZ	254 221 PZPZ	250 321 PZPZ	254 321 PZPZ	250 421 PZPZ	254 421 PZPZ
300-0-300 Volts	250 121 RXRX	250 221 RXRX	254 221 RXRX	250 321 RXRX	254 321 RXRX	250 421 RXRX	254 421 RXRX
500 -0-500 Volts	.....	.....	.....	250 321 SFSF	254 321 SFSF	250 421 SFSF	254 421 SFSF
600-0-600 Volts	.....	.....	.....	250 321 SJSJ	254 321 SJSJ	250 421 SJSJ	254 421 SJSJ
DC VOLTMETERS — EXPANDED SCALE							
24-30 Volts	.....	.....	.....	250 338 NNNN	254 338 NNNN	250 438 NNNN	254 438 NNNN
110-130 Volts	.....	.....	.....	250 338 PNPN	254 338 PNPN	250 438 PNPN	254 438 PNPN
220-260 Volts	.....	.....	.....	250 338 RTRT	254 338 RTRT	250 438 RTRT	254 438 RTRT
DC VOLTMETERS — ZERO-CENTER, RATED 1-0-1 mA DC, FOR USE WITH EXTERNAL RESISTORS, RESISTORS NOT INCLUDED (SEE PAGE 29 FOR RESISTORS)							
SCALE ONLY							
500-0-500 Volts	250 105 FASF	250 205 FASF	254 205 FASF	.....	.....	.....	.....
600-0-600 Volts	250 105 FASJ	250 205 FASJ	254 205 FASJ	.....	.....	.....	.....
750-0-750 Volts	250 105 FASM	250 205 FASM	254 205 FASM	250 305 FASM	254 305 FASM	250 405 FASM	254 405 FASM

DC Ammeters

DC MICROAMMETERS — ZERO-LEFT							
20 µA	250 100 CFCF	250 200 CFCF	.....	250 300 CFCF	.....	.....	.....
50 µA	250 100 CYCY	250 200 CYCY	.....	250 300 CYCY	.....	250 400 CYCY	.....
100 µA	250 100 DRDR	250 200 DRDR	.....	250 300 DRDR	.....	250 400 DRDR	.....
200 µA	250 100 EAEA	250 200 EAEA	254 200 EAEA	250 300 EAEA	254 300 EAEA	250 400 EAEA	254 400 EAEA
500 µA	250 100 EMEM	250 200 EMEM	254 200 EMEM	250 300 EMEM	254 300 EMEM	250 400 EMEM	254 400 EMEM
DC MICROAMMETERS — ZERO-CENTER							
20-0-20 µA	250 101 CFCF	250 201 CFCF	.....	250 301 CFCF	.....	.....	.....
50-0-50 µA	250 101 CYCY	250 201 CYCY	.....	250 301 CYCY	.....	250 401 CYCY	.....
100-0-100 µA	250 101 DRDR	250 201 DRDR	254 201 DRDR	250 301 DRDR	254 301 DRDR	250 401 DRDR	254 401 DRDR
200-0-200 µA	250 101 EAEA	250 201 EAEA	254 201 EAEA	250 301 EAEA	254 301 EAEA	250 401 EAEA	254 401 EAEA
500-0-500 µA	250 101 EMEM	250 201 EMEM	254 201 EMEM	250 301 EMEM	254 301 EMEM	250 401 EMEM	254 401 EMEM
DC MICROAMMETERS — ZERO-LEFT							
1 mA	250 100 FAFA	250 200 FAFA	254 200 FAFA	250 300 FAFA	254 300 FAFA	250 400 FAFA	254 400 FAFA
5 mA	250 100 FXFX	250 200 FXFZ	254 200 FXFX	250 300 FXFX	254 300 FXFX	250 400 FXFX	254 400 FXFX
10 mA	250 100 GZGZ	250 200 GZGZ	254 200 GZGZ	250 300 GZGZ	254 300 GZGZ	250 400 GZGZ	254 400 GZGZ
20 mA	250 100 HFHF	250 200 HFHF	254 200 HFHF	250 300 HFHF	254 300 HFHF	250 400 HFHF	254 400 HFHF
25 mA	250 100 HJHJ	250 200 HJHJ	254 200 HJHJ	250 300 HJHJ	254 300 HJHJ	250 400 HJHJ	254 400 HJHJ
30 mA	250 100 HMHM	250 200 HMHM	254 200 HMHM	250 300 HMHM	254 300 HMHM	250 400 HMHM	254 400 HMHM
50 mA	250 100 HYHY	250 200 HYHY	254 200 HYHY	250 300 HYHY	254 300 HYHY	250 400 HYHY	254 400 HYHY
80 mA	250 100 JJJJ	250 200 JJJJ	254 200 JJJJ	250 300 JJJJ	254 300 JJJJ	250 400 JJJJ	254 400 JJJJ
100 mA	250 100 JRJR	250 200 JRJR	254 200 JRJR	250 300 JRJR	254 300 JRJR	250 400 JRJR	254 400 JRJR
150 mA	250 100 JXJX	254 200 JXJX	254 200 JXJX	250 300 JXJX	254 300 JXJX	250 400 JXJX	254 400 JXJX
200 mA	250 100 KAKA	250 200 KAKA	254 200 KAKA	250 300 KAKA	254 300 KAKA	250 400 KAKA	254 400 KAKA
250 mA	250 100 KDKD	250 200 KDKD	254 200 KDKD	250 300 KDKD	254 300 KDKD	250 400 KDKD	254 400 KDKD
300 mA	250 100 KGKG	250 200 KGKG	254 200 KGKG	250 300 KGKG	254 300 KGKG	250 400 KGKG	254 400 KGKG
500 mA	250 100 KMKM	250 200 KMKM	254 200 KMKM	250 300 KMKM	254 300 KMKM	250 400 KMKM	254 400 KMKM
800 mA	250 100 KWKW	250 200 KWKW	254 200 KWKW	250 300 KWKW	254 300 KWKW	250 400 KWKW	254 400 KWKW

DC Ammeters Cont'd

Size	1½	2½		3½		4½	
Type / Rating & Scale	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC MILLIAMMETERS — ZERO-CENTER							
1-0-1 mA	250 101 FAFA	250 201 FAFA	254 201 FAFA	250 301 FAFA	254 301 FAFA	250 401 FAFA	254 401 FAFA
5-0-5 mA	250 101 FXFX	250 201 FXFX	254 201 FXFX	250 301 FXFGX	254 301 FXFX	250 401 FXFX	254 401 FXFX
10-0-10 mA	250 101 GZGZ	250 201 GZGZ	254 201 GZGZ	250 301 GZGZ	254 301 GZGZ	250 401 GZGZ	254 401 GZGZ
20-0-20 mA	250 101 HFHF	250 201 HFHF	254 201 HFHF	250 301 HFHF	254 301 HFHF	250 401 HFHF	254 401 HFHF
25-0-25 mA	250 101 HJHJ	250 201 HJHJ	254 201 HJHJ	250 301 HJHJ	254 301 HJHJ	250 401 HJHJ	254 401 HJHJ
30-0-30 mA	250 101 HMHM	250 201 HMHM	254 201 HMHM	250 301 HMHM	254 301 HMHM	250 401 HMHM	254 401 HMHM
50-0-50 mA	250 101 HYHY	250 201 HYHY	254 201 HYHY	250 301 HYHY	254 301 HYHY	250 401 HYHY	254 401 HYHY
100-0-100 mA	250 101 JRJR	250 201 JRJR	254 201 JRJR	250 301 JRJR	254 301 JRJR	250 401 JRJR	254 401 JRJR
150-0-150 mA	250 101 JXJX	250 201 JXJX	254 201 JXJX	250 301 JXJX	254 301 JXJX	250 401 JXJX	254 401 JXJX
200-0-200 mA	250 101 KAKA	250 201 KAKA	254 201 KAKA	250 301 KAKA	254 301 KAKA	250 401 KAKA	254 401 KAKA
250-0-250 mA	250 101 KDKD	250 201 KDKD	254 201 KDKD	250 301 KDKD	254 301 KDKD	250 401 KDKD	254 401 KDKD
300-0-300 mA	250 101 KGKG	250 201 KGKG	254 201 KGKG	250 301 KGKG	254 301 KGKG	250 401 KGKG	254 401 KGKG
500-0-500 mA	250 101 KMKM	250 201 KMKM	254 201 KMKM	250 301 KMKM	254 301 KMKM	250 401 KMKM	254 401 KMKM
DC AMMETERS — ZERO-LEFT							
1 Amp	250 100 LALA	250 200 LALA	254 200 LALA	250 300 LALA	254 300 LALA	250 400 LALA	254 400 LALA
1.5 Amp	250 100 LCLC	250 200 LCLC	254 200 LCLC	250 300 LCLC	254 300 LCLC	250 400 LCLC	254 400 LCLC
2 Amp	250 100 LELE	250 200 LELE	254 200 LELE	250 300 LELE	254 300 LELE	250 400 LELE	254 200 LELE
3 Amp	250 100 LJLJ	250 200 LJLJ	254 200 LJLJ	250 300 LJLJ	254 300 LJLJ	250 400 LJLJ	254 400 LJLJ
5 Amp	250 100 LSLS	250 200 LSLS	254 200 LSLS	250 300 LSLS	254 300 LSLS	250 400 LSLS	254 400 LSLS
10 Amp	250 100 MTMT	250 200 MTMT	254 200 MTMT	250 300 MTMT	254 300 MTMT	250 400 MTMT	254 400 MTMT
15 Amp	250 100 NDND	250 200 NDND	254 200 NDND	250 300 NDND	254 300 NDND	250 400 NDND	254 400 NDND
20 Amp	.....	250 200 NGNG	254 200 NGNG	250 300 NGNG	254 300 NGNG	250 400 NGNG	254 400 NGNG
30 Amp	.....	250 200 NLNL	254 200 NLNL	250 300 NLNL	254 300 NLNL	250 400 NLNL	254 400 NLNL
50 Amp	.....	.....	.....	250 300 NTNT	250 300 NTNT	250 400 NTNT	254 400 NTNT
DC AMMETERS — ZERO-LEFT, 50 mV, SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*							
SCALE ONLY							
20 Amp	250 124 ECNG	250 224 ECNG	254 224 ECNG	250 324 ECNG	254 324 ECNG	250 424 ECNG	254 424 ECNG
30 Amp	250 124 ECNL	250 224 ECNL	254 224 ECNL	250 324 ECNL	254 324 ECNL	250 424 ECNL	254 424 ECNL
50 Amp	250 124 ECNT	250 224 ECNT	254 224 ECNT	250 324 ECNT	254 324 ECNT	250 424 ECNT	254 424 ECNT
75 Amp	250 124 ECPB	250 224 ECPB	254 224 ECPB	250 324 ECPB	254 324 ECPB	250 424 ECPB	254 424 ECPB
100 Amp	250 124 ECPK	250 224 ECPK	254 224 ECPK	250 324 ECPK	254 324 ECPK	250 424 ECPK	254 424 ECPK
150 Amp	250 124 ECPZ	250 224 ECPZ	254 224 ECPZ	250 324 ECPZ	254 324 ECPZ	250 424 ECPZ	254 424 ECPZ
200 Amp	250 124 ECRL	250 224 ECRL	254 224 ECRL	250 324 ECRL	254 324 ECRL	250 424 ECRL	254 424 ECRL
250 Amp	250 124 ECRS	250 224 ECRS	254 224 ECRS	250 324 ECRS	254 324 ECRS	250 424 ECRS	254 424 ECRS
300 Amp	250 124 ECRX	250 224 ECRX	254 224 ECRX	250 324 ECRX	254 324 ECRX	250 424 ECRX	254 424 ECRX
400 Amp	250 124 ECSC	250 224 ECSC	254 224 ECSC	250 324 ECSC	254 324 ECSC	250 424 ECSC	254 424 ECSC
500 Amp	250 124 ECSF	250 224 ECSF	254 224 ECSF	250 324 ECSF	254 324 ECSF	250 424 ECSF	254 424 ECSF
600 Amp	250 124 ECSJ	250 224 ECSJ	254 224 ECSJ	250 324 ECSJ	254 324 ECSJ	250 424 ECSJ	254 424 ECSJ
800 Amp	250 124 ECSN	250 224 ECSN	254 224 ECSN	250 324 ECSN	254 324 ECSN	250 424 ECSN	254 424 ECSN
1 Kiloamp	250 124 ECVA	250 224 ECVA	254 224 ECVA	250 324 ECVA	254 324 ECVA	250 424 ECVA	254 424 ECVA
1.5 Kiloamp	250 124 ECVC	250 224 ECVC	254 224 ECVC	250 324 ECVC	254 324 ECVC	250 424 ECVC	254 424 ECVC
2 Kiloamp	250 124 ECVE	250 224 ECVE	254 224 ECVE	250 324 ECVE	254 324 ECVE	250 424 ECVE	254 424 ECVE
DC AMMETERS — ZERO-LEFT, 100 mV, SHUNT RATED (LEAD RES. RANGE: .04-.08Ω)*							
SCALE ONLY							
20 Amp	250 124 GBNG	250 224 GBNG	254 224 GBNG	250 324 GBNG	254 324 GBNG	250 424 GBNG	254 424 GBNG
40 Amp	250 124 GBNP	250 224 GBNP	254 224 GBNP	250 324 GBNP	254 324 GBNP	250 424 GBNP	254 424 GBNP
50 Amp	250 124 GBNT	250 224 GBNT	254 224 GBNT	250 324 GBNT	254 324 GBNT	250 424 GBNT	254 424 GBNT
75 Amp	250 124 GBPB	250 224 GBPB	254 224 GBPB	250 324 GBPB	254 324 GBPB	250 424 GBPB	254 424 GBPB
100 Amp	250 124 GBPK	250 224 GBPK	254 224 GBPK	250 324 GBPK	254 324 GBPK	250 424 GBPK	254 424 GBPK
150 Amp	250 124 GBPZ	250 224 GBPZ	254 224 GBPZ	250 324 GBPZ	254 324 GBPZ	250 424 GBPZ	254 424 GBPZ
200 Amp	250 124 GBRL	250 224 GBRL	254 224 GBRL	250 324 GBRL	254 324 GBRL	250 424 GBRL	254 424 GBRL
250 Amp	250 124 GBRS	250 224 GBRS	254 224 GBRS	250 324 GBRS	254 324 GBRS	250 424 GBRS	254 424 GBRS
300 Amp	250 124 GBRX	250 224 GBRX	254 224 GBRX	250 324 GBRX	254 324 GBRX	250 424 GBRX	254 424 GBRX
400 Amp	250 124 GBSC	250 224 GBSC	254 224 GBSC	250 324 GBSC	254 324 GBSC	250 424 GBSC	254 424 GBSC
500 Amp	250 124 GBSF	250 224 GBSF	254 224 GBSF	250 324 GBSF	254 324 GBSF	250 424 GBSF	254 424 GBSF
600 Amp	250 124 GBSJ	250 224 GBSJ	254 224 GBSJ	250 324 GBSJ	254 324 GBSJ	250 424 GBSJ	254 424 GBSJ
800 Amp	250 124 GBSN	250 224 GBSN	254 224 GBSN	250 324 GBSN	254 324 GBSN	250 424 GBSN	254 424 GBSN
1Kiloamp	250 124 GBVA	250 224 GBVA	254 224 GBVA	250 324 GBVA	254 324 GBVA	250 424 GBVA	254 424 GBVA
2 Kiloamp	250 124 GBVE	250 224 GBVE	254 224 GBVE	250 324 GBVE	254 324 GBVE	250 424 GBVE	254 424 GBVE

*Shunts are not included: For 50mV shunts, see page 29

DC Ammeters Cont'd

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC AMMETERS — ZERO-CENTER							
1-0-1 Amp	250 101 LALA	250 201 LALA	254 201 LALA	250 301 LALA	254 301 LALA	250 401 LALA	254 401 LALA
2-0-2 Amp	250 101 LELE	250 201 LELE	254 201 LELE	250 301 LELE	254 301 LELE	250 401 LELE	254 401 LELE
5-0-5 Amp	250 101 LSLS	250 201 LSLS	254 201 LSLS	250 301 LSLS	254 301 LSLS	250 401 LSLS	254 401 LSLS
10-0-10 Amp	250 101 MTMT	250 201 MTMT	254 201 MTMT	250 301 MTMT	254 301 MTMT	250 401 MTMT	254 401 MTMT
15-0-15 Amp	.....	250 201 NDND	254 201 NDND	250 301 NDND	254 301 NDND	250 401 NDND	254 401 NDND
20-0-20 Amp	.....	250 201 NGNG	254 201 NGNG	250 301 NGNG	254 301 NGNG	250 401 NGNG	254 401 NGNG
30-0-30 Amp	.....	250 201 NLNL	254 201 NLNL	250 301 NLNL	254 301 NLNL	250 401 NLNL	254 401 NLNL
50-0-50 Amp	.....	.....	.....	250 301 NTNT	254 301 NTNT	250 401 NTNT	254 401 NTNT
DC AMMETERS — ZERO-CENTER, 50 mV, SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*							
SCALE ONLY							
20-0-20 Amp	250 125 ECNG	250 225 ECNG	.....	250 325 ECNG	.....	.....	.....
40-0-40 Amp	250 125 ECNP	250 225 ECNP	254 225 ECNP	250 325 ECNP	254 325 ECNP	250 425 ECNP	254 425 ECNP
50-0-50 Amp	250 125 ECNT	250 225 ECNT	254 225 ECNT	250 325 ECNT	254 325 ECNT	250 425 ECNT	254 425 ECNT
75-0-75 Amp	250 125 ECPB	250 225 ECPB	254 225 ECPB	250 325 ECPB	254 325 ECPB	250 425 ECPB	254 425 ECPB
100-0-100 Amp	250 125 ECPK	250 225 ECPK	254 225 ECPK	250 325 ECPK	254 325 ECPK	250 425 ECPK	254 425 ECPK

*Shunts are not included: For 50mV shunts, see page 29

AC Voltmeters

Size	1½	2½	3½	4½
Rating & Scale / Type		200 Series	200 Series	200 Series
AC VOLTMETERS — SELF-CONTAINED, IRON VANE TYPE, PIVOT AND JEWEL 60 Hz				
3 Volts	.....	250 244 LJLJ	250 344 LJLJ	250 444 LJLJ
5 Volts	.....	250 244 LSLS	250 344 LSLS	250 444 LSLS
10 Volts	.....	250 244 MTMT	250 344 MTMT	250 444 MTMT
15 Volts	.....	250 244 NDND	250 344 NDND	250 444 NDND
30 Volts	.....	250 244 NLNL	250 344 NLNL	250 444 NLNL
50 Volts	.....	250 244 NTNT	250 344 NTNT	250 444 NTNT
100 Volts	.....	250 244 PKPK	250 344 PKPK	250 444 PKPK
150 Volts	.....	250 244 PZPZ	250 344 PZPZ	250 444 PZPZ
300 Volts	.....	250 244 RXRX	250 344 RXRX	250 444 RXRX
500 Volts	.....	.....	250 344 SFSF	250 444 SFSF
600 Volts	.....	.....	250 344 SJSJ	250 444 SJSJ
AC VOLTMETERS — SELF-CONTAINED, IRON VANE TYPE, PIVOT AND JEWEL 400 Hz				
150 Volts	.....	250 245 PZPZ	250 345 PZPZ	250 445 PZPZ
300 Volts	.....	250 245 RXRX	250 345 RXRX	250 445 RXRX
AC VOLTMETERS — TRANSFORMER RATED, 0-150 VOLTS, PIVOT AND JEWEL, IRON VANE TYPE, 60 Hz. (See page 29 for Transformers)				
SCALE ONLY				
600 Volts	.....	250 244 PZSJ	250 344 PZSJ	250 444 PZSJ
750 Volts	.....	250 244 PZSM	250 344 PZSM	250 444 PZSM
3 kV	.....	250 244 PZVJ	250 344 PZVJ	250 444 PZVJ

AC VOLTMETERS — EXPANDED SCALE, RECTIFIER TYPE

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
110-130 Volts	.....	.....	.....	250 337 PNPN	254 337 PNPN	250 437 PNPN	254 437 PNPN
105-125 Volts	.....	.....	.....	250 337 PTPT	254 337 PTPT	250 437 PTPT	254 437 PTPT

IP7014971

AC Voltmeters Cont'd

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel

AC VOLTMETERS — SELF-CONTAINED, RECTIFIER TYPE

10 Volts	250 130 MTMT	250 230 MTMT	254 230 MTMT	250 330 MTMT	254 330 MTMT	250 430 MTMT	254 430 MTMT
15 Volts	250 130 NDND	250 230 NDND	254 230 NDND	250 330 NDND	254 330 NDND	250 430 NDND	254 430 NDND
20 Volts	250 130 NGNG	250 230 NGNG	254 230 NGNG	250 330 NGNG	254 330 NGNG	250 430 NGNG	254 430 NGNG
25 Volts	250 130 NJNJ	250 230 NJNJ	254 230 NJNJ	250 330 NJNJ	254 330 NJNJ	250 430 NJNJ	254 430 NJNJ
30 Volts	250 130 NLNL	250 230 NLNL	254 230 NLNL	250 330 NLNL	254 330 NLNL	250 430 NLNL	254 430 NLNL
50 Volts	250 130 NTNT	250 230 NTNT	254 230 NTNT	250 330 NTNT	254 330 NTNT	250 430 NTNT	254 430 NTNT
80 Volts	250 130 PDPD	250 230 PDPD	254 230 PDPD	250 330 PDPD	254 330 PDPD	250 430 PDPD	254 430 PDPD
100 Volts	250 130 PKPK	250 230 PKPK	254 230 PKPK	250 330 PKPK	254 330 PKPK	250 430 PKPK	254 430 PKPK
150 Volts	250 130 PZPZ	250 230 PZPZ	254 230 PZPZ	250 330 PZPZ	254 330 PZPZ	250 430 PZPZ	254 430 PZPZ
200 Volts	.....	.....	.....	250 330 RLRL	254 330 RLRL	250 430 RLRL	254 430 RLRL
250 Volts	.....	.....	.....	250 330 RSRS	254 330 RSRS	250 430 RSRS	254 430 RSRS
300 Volts	.....	.....	.....	250 330 RXRX	254 330 RXRX	250 430 RXRX	254 430 RXRX

AC Ammeters

AC MICROAMMETERS AND MILLIAMMETERS — RECTIFIER TYPE

500 µA	250 110 EMEM	250 210 EMEM	254 210 EMEM	250 310 EMEM	254 310 EMEM	250 410 EMEM	254 410 EMEM
800 µA	250 110 EWEW	250 210 EWEW	254 210 EWEW	250 310 EWEW	254 310 EWEW	250 410 EWEW	254 410 EWEW
1 mA	250 110 FAFA	250 210 FAFA	254 210 FAFA	250 310 FAFA	254 310 FAFA	250 410 FAFA	254 410 FAFA
1.5 mA	250 110 FDFD	250 210 FDFD	254 210 FDFD	250 310 FDFD	254 310 FDFD	250 410 FDFD	254 410 FDFD
2 mA	250 110 FGFG	250 210 FGFG	254 210 FGFG	250 310 FGFG	254 310 FGFG	250 410 FGFG	254 410 FGFG
3 mA	250 110 FNFN	250 210 FNFN	254 210 FNFN	250 310 FNFN	254 310 FNFN	250 410 FNFN	254 410 FNFN
5 mA	250 110 FXFX	250 210 FXFX	254 210 FXFX	250 310 FXFX	254 310 FXFX	250 410 FXFX	254 410 FXFX
10 mA	250 110 GZGZ	250 210 GZGZ	254 210 GZGZ	250 310 GZGZ	254 310 GZGZ	250 410 GZGZ	254 410 GZGZ
20 mA	250 110 HFHF	250 210 HFHF	254 210 HFHF	250 310 HFHF	254 310 HFHF	250 410 HFHF	254 410 HFHF

Size	1½	2½	3½	4½
Rating & Scale / Type		200 Series	200 Series	200 Series

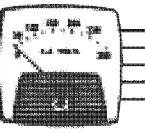
AC MILLIAMMETERS — SELF-CONTAINED, 25-400 Hz, IRON VANE, PIVIT AND JEWEL

10 mA	.....	250 240 GZGZ	250 340 GZGZ	250 440 GZGZ
25 mA	.....	250 240 HJHJ	250 340 HJHJ	250 440 HJHJ
50 mA	.....	250 240 HYHY	250 340 HYHY	250 440 HYHY
100 mA	.....	250 240 JRJR	250 340 JRJR	250 440 JRJR
200 mA	.....	250 240 KAKA	250 340 KAKA	250 440 KAKA
500 mA	.....	250 240 KMKM	250 340 KMKM	250 440 KMKM

AC AMMETERS — SELF-CONTAINED, 25-400 Hz, IRON VANE, PIVOT AND JEWEL

1 Amp	.....	250 240 LALA	250 340 LALA	250 440 LALA
3 Amp	.....	250 240 LJLJ	250 340 LJLJ	250 440 LJLJ
5 Amp	.....	250 240LSLS	250 340 LSLS	250 440 LSLS
8 Amp	.....	250 240 MJMJ	250 340 MJMJ	250 440 MJMJ
10 Amp	.....	250 240 MTMT	250 340 MTMT	250 440 MTMT
15 Amp	.....	250 240 NDND	250 340 NDND	250 440 NDND
20 Amp	.....	250 240 NGNG*	250 340 NGNG*	250 440 NGNG*
30 Amp	.....	250 240 NLNL*	250 340 NLNL*	250 440 NLNL*
50 Amp	.....	.....	250 340 NTNT*	250 440 NTNT*
80 Amp	.....	.....	250 340 PDPD*	250 440 PDPD*

* External Magnetic shield included



AC Ammeters Cont'd

Size	1½	2½	3½	4½
Type / Rating & Scale		200 Series	200 Series	200 Series

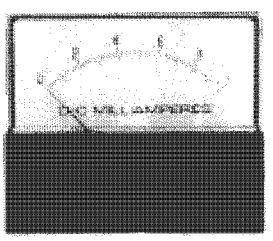
AC AMMETERS — TRANSFORMER-RATED, 0-5 AMPERES, 25-500 Hz, PIVOT AND JEWEL, IRON VANE

(See page 29 for Transformers)

10 Amp	.....	250 240 LSMT	250 340 LSMT	250 440 LSMT
15 Amp	.....	250 240 LSND	250 340 LSND	250 440 LSND
20 Amp	.....	250 240 LSNG	250 340 LSNG	250 440 LSNG
30 Amp	.....	250 240 LSNL	250 340 LSNL	250 440 LSNL
40 Amp	.....	250 240 LSNP	250 340 LSNP	250 440 LSNP
50 Amp	.....	250 240 LSNT	250 340 LSNT	250 440 LSNT
75 Amp	.....	250 240 LSPB	250 340 LSPB	250 440 LSPB
80 Amp	.....	250 240 LSPD	250 340 LSPD	250 440 LSPD
100 Amp	.....	250 240 LSPK	250 340 LSPK	250 440 LSPK
150 Amp	.....	250 240 LSPZ	250 340 LSPZ	250 440 LSPZ
200 Amp	.....	250 240 LSRL	250 340 LSRL	250 440 LSRL
300 Amp	.....	250 240 LSRX	250 340 LSRX	250 440 LSRX
400 Amp	.....	250 240 LSSC	250 340 LSSC	250 440 LSSC
500 Amp	.....	250 240 LSSF	250 340 LSSF	250 440 LSSF
600 Amp	.....	250 240 LSSJ	250 340 LSSJ	250 440 LSSJ
800 Amp	.....	250 240 LSSN	250 340 LSSN	250 440 LSSN
1 Kiloamp	.....	250 240 LSVA	250 340 LSVA	250 440 LSVA
1.2 Kiloamp	.....	250 240 LSVB	250 340 LSVB	250 440 LSVB
1.5 Kiloamp	.....	250 240 LSVC	250 340 LSVC	250 440 LSVC
2.0 Kiloamp	.....	250 240 LSVE	250 340 LSVE	250 440 LSVE
3.0 Kiloamp	.....	250 240 LSVJ	250 340 LSVJ	250 440 LSVJ

SCALE ONLY

YOKOGAWA ◆ Horizon Line



Type 251 and 255
Horizon Line

Specifications

Accuracy: All DC and AC iron-vane; ±2% of full-scale, AC rectifier type; ±3% of full scale (with 60 Hz sine wave at 25° C). When standard 60 Hz iron vane ammeters are used at the extreme limits of 20 or 400 Hz, additional error (approx. .75%) may be experienced. Expanded-scale voltmeters; ±.5% of full scale value.

ANSI Specification: All meters meet ANSI Specifications C-39.1.

Overload: Voltmeters (AC and DC) - 50% momentary, 20% sustained. Ammeters (AC and DC) momentary: 10 times the rated current for 10 consecutive intervals of .5 second with a 1 minute interval between successive applications; sustained: 20% for six hours.

Scale Data: 90 degree rotation.

Scale Length:

Size	Horizon Line
1½"	1.50"
2½"	2.06"
3½"	2.88"
4½"	3.93"

Insulation Level: All meters (except 1½"), 2600 VRMS Hi-pot, 1½"-1500 VRMS Hi-pot.

Burden Data: AC ammeter-5 amps, 0.5 va max. 0.5 power-factor lagging, @60 Hz. AC Voltmeter-unity power factor.

Response Time and Overshoot: Response time: 3 seconds (max.) for 2½", 3½", 4½" size for microammeters: 2 seconds (max.) for all other DC ratings, and 2.5 seconds (max.) for AC ratings. Maximum of 40% overshoot.

Dimensions: See page 34-35.

How To Order

To Order Horizon Line panel meters use the appropriate catalog numbers provided in the tables. Taut band instruments have a 251 prefix number, Pivot & jewel instruments have a 255 prefix number, except AC Iron Vane prefix which is 251.

Ordering Examples:

1. 21/2", 300 V DC Voltmeter, zero left, taut band - 251 220 RXRX
2. 21/2", 300 V DC Voltmeter, zero left, pivot & jewel - 255 220 RXRX
3. 21/2", 300 VAC (Iron Vane) pivot & jewel - 251 244 RXRX

Severe-duty meters are available to meet UL 1437 requirements. UL/CSA version, with flame retardant window and base, is not offered in 11/2". To order, add /UL or /CSA after catalog number, or contact factory. For ratings and scales not listed contact factory.

DC Voltmeters

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC VOLTMETERS - ZERO-LEFT							
1.0 Volts	251 120 LALA	251 220 LALA	255 220 LALA	251 320 LALA	255 320 LALA	251 420 LALA	255 420 LALA
1.5 Volts	251 120 LCLC	251 220 LCLC	255 220 LCLC	251 320 LCLC	255 320 LCLC	251 420 LCLC	255 420 LCLC
3 Volts	251 120 LJLJ	251 220 LJLJ	255 220 LJLJ	251 320 LJLJ	255 320 LJLJ	251 420 LJLJ	255 420 LJLJ
5 Volts	251 120 LSLS	251 220 LSLS	255 220 LSLS	251 320 LSLS	255 320 LSLS	251 420 LSLS	255 420 LSLS
8 Volts	251 120 MJMJ	251 220 MJMJ	255 220 MJMJ	251 320 MJMJ	255 320 MJMJ	251 420 MJMJ	255 420 MJMJ
10 Volts	251 120 MTMT	251 220 MTMT	255 220 MTMT	251 320 MTMT	255 320 MTMT	251 420 MTMT	255 420 MTMT
15 Volts	251 120 NDND	251 220 NDND	255 220 NDND	251 320 NDND	255 320 NDND	251 420 NDND	255 420 NDND
30 Volts	251 120 NLNL	251 220 NLNL	255 220 NLNL	251 320 NLNL	255 320 NLNL	251 420 NLNL	255 420 NLNL
40 Volts	251 120 NPNP	251 220 NPNP	255 220 NPNP	251 320 NPNP	255 320 NPNP	251 420 NPNP	255 420 NPNP
50 Volts	251 120 NTNT	251 220 NTNT	255 220 NTNT	251 320 NTNT	255 320 NTNT	251 420 NTNT	255 420 NTNT
80 Volts	251 120 PDPD	251 220 PDPD	255 220 PDPD	251 320 PDPD	255 320 PDPD	251 420 PDPD	255 420 PDPD
100 Volts	251 120 PKPK	251 220 PKPK	255 220 PKPK	251 320 PKPK	255 320 PKPK	251 420 PKPK	255 420 PKPK
150 Volts	251 120 PZPZ	251 220 PZPZ	255 220 PZPZ	251 320 PZPZ	255 320 PZPZ	251 420 PZPZ	255 420 PZPZ
200 Volts	251 120 RLRL	251 220 RLRL	255 220 RLRL	251 320 RLRL	255 320 RLRL	251 420 RLRL	255 420 RLRL
250 Volts	251 120 RSRS	251 220 RSRS	255 220 RSRS	251 320 RSRS	255 320 RSRS	251 420 RSRS	255 420 RSRS
300 Volts	251 120 RXRX	251 220 RXRX	255 220 RXRX	251 320 RXRX	255 320 RXRX	251 420 RXRX	255 420 RXRX
500 Volts	.....	.....	.....	251 320 SFSF	255 320 SFSF	251 420 SFSF	255 420 SFSF
600 Volts	.....	.....	.....	251 320 SJSJ	255 320 SJSJ	251 420 SJSJ	255 420 SJSJ
DC VOLTMETERS — ZERO-LEFT, RATED 0-1 mA DC, FOR USE WITH EXTERNAL RESISTORS, RESISTORS NOT INCLUDED (SEE PAGE 29 FOR RESISTORS)							
SCALE ONLY							
500 Volts	251 104 FASF	251 204 FASF	255 204 FASF	.....	.....	.....	.....
600 Volts	251 104 FASJ	251 204 FASJ	255 204 FASJ	.....	.....	.....	.....
750 Volts	251 104 FASM	251 204 FASM	255 204 FASM	251 304 FASM	255 304 FASM	251 404 FASM	255 404 FASM
DC VOLTMETERS — ZERO-CENTER							
5-0-5 Volts	251 121 LSLS	251 221 LSLS	255 221 LSLS	251 321 LSLS	255 321 LSLS	251 421 LSLS	255 421 LSLS
10-0-10 Volts	251 121 MTMT	251 221 MTMT	255 221 MTMT	251 321 MTMT	255 321 MTMT	251 421 MTMT	255 421 MTMT
30-0-30 Volts	251 121 NLNL	251 221 NLNL	255 221 NLNL	251 321 NLNL	255 321 NLNL	251 421 NLNL	255 421 NLNL
50-0-50 Volts	251 121 NTNT	251 221 NTNT	255 221 NTNT	251 321 NTNT	255 321 NTNT	251 421 NTNT	255 421 NTNT
80-0-80 Volts	251 121 PDPD	251 221 PDPD	255 221 PDPD	251 321 PDPD	255 321 PDPD	251 421 PDPD	255 421 PDPD
150-0-150 Volts	251 121 PZPZ	251 221 PZPZ	255 221 PZPZ	251 321 PZPZ	255 321 PZPZ	251 421 PZPZ	255 421 PZPZ
300-0-300 Volts	251 121 RXRX	251 221 RXRX	255 221 RXRX	251 321 RXRX	255 321 RXRX	251 421 RXRX	255 421 RXRX
500-0-500 Volts	.....	.....	.....	251 321 SFSF	255 321 SFSF	251 421 SFSF	255 421 SFSF
600-0-600 Volts	.....	.....	.....	251 321 SJSJ	255 321 SJSJ	251 421 SJSJ	255 421 SJSJ
DC VOLTMETERS — ZERO-CENTER, RATED 1-0-1 mA, DC, FOR USE WITH EXTERNAL RESISTORS, RESISTORS NOT INCLUDED (SEE PAGE 29 FOR RESISTORS)							
SCALE ONLY							
500-0-500 Volts	251 105 FASF	251 205 FASF	255 205 FASF	.....	.....	.....	.....
600-0-600 Volts	251 105 FASJ	251 205 FASJ	255 205 FASJ	.....	.....	.....	.....
750-0-750 Volts	251 105 FASM	251 205 FASM	255 205 FASM	251 305 FASM	255 305 FASM	251 405 FASM	255 405 FASM
DC VOLTMETERS — EXPANDED SCALE; ZENER DIODE TYPE							
24-30 Volts	.....	.....	.....	251 338 NNNN	255 338 NNNN	251 438 NNNN	255 438 NNNN
110-130 Volts	.....	.....	.....	251 338 PNPN	255 338 PNPN	251 438 PNPN	255 438 PNPN
220-260 Volts	.....	.....	.....	251 338 RTRT	255 338 RTRT	251 438 RTRT	255 438 RTRT

DC Ammeters

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC MICROAMMETERS — ZERO-LEFT							
20 µA	251 100 CFCF	251 200 CFCF	.....	251 300 CFCF	.....	.....	.....
50 µA	251 100 CYCY	251 200 CYCY	.....	251 300 CYCY	.....	251 400 CYCY	.....
100 µA	251 100 DRDR	251 200 DRDR	.....	251 300 DRDR	.....	251 400 DRDR	.....
200 µA	251 100 EAEA	251 200 EAEA	255 200 EAEA	251 300 EAEA	255 300 EAEA	251 400 EAEA	255 400 EAEA
500 µA	251 100 EMEM	251 200 EMEM	255 200 EMEM	251 300 EMEM	255 300 EMEM	251 400 EMEM	255 400 EMEM

DC Ammeters Cont'd

Size	1½	2½		3½		4½	
Rating & Scale \ Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC MICROAMMETERS — ZERO-CENTER							
20-0-20 µA	251 101 CFCF	251 201 CFCF	.....	251 301 CFCF	.....	.....	.....
50-0-50 µA	251 101 CYCY	251 201 CYCY	.....	251 301 CYCY	.....	251 401 CYCY	.....
100-0-100 µA	251 101 DRDR	251 201 DRDR	255 201 DRDR	251 301 DRDR	255 301 DRDR	251 401 DRDR	255 401 DRDR
200-0-200 µA	251 101 EAEA	251 201 EAEA	255 201 EAEA	251 301 EAEA	255 301 EAEA	251 401 EAEA	255 401 EAEA
500-0-500 µA	251 101 EMEM	251 201 EMEM	255 201 EMEM	251 301 EMEM	255 301 EMEM	251 401 EMEM	255 401 EMEM
DC MILLIAMMETERS — ZERO-LEFT							
1 mA	251 100 FAFA	251 200 FAFA	255 200 FAFA	251 300 FAFA	255 300 FAFA	251 400 FAFA	255 400 FAFA
5 mA	251 100 FXFX	251 200 FXFX	255 200 FXFX	251 300 FXFX	255 300 FXFX	251 400 FXFX	255 400 FXFX
10 mA	251 100 GZGZ	251 200 GZGZ	255 200 GZGZ	251 300 GZGZ	255 300 GZGZ	251 400 GZGZ	255 400 GZGZ
20 mA	251 100 HFHF	251 200 HFHF	255 200 HFHF	251 300 HFHF	255 300 HFHF	251 400 HFHF	255 400 HFHF
25 mA	251 100 HJHJ	251 200 HJHJ	255 200 HJHJ	251 300 HJHJ	255 300 HJHJ	251 400 HJHJ	255 400 HJHJ
30 mA	251 100 HMHM	251 200 HMHM	255 200 HMHM	251 300 HMHM	255 300 HMHM	251 400 HMHM	255 400 HMHM
50 mA	251 100 HYHY	251 200 HYHY	255 200 HYHY	251 300 HYHY	255 300 HYHY	251 400 HYHY	255 400 HYHY
80 mA	251 100 JJJJ	251 200 JJJJ	255 200 JJJJ	251 300 JJJJ	255 300 JJJJ	251 400 JJJJ	255 400 JJJJ
100 mA	251 100 JRJR	251 200 JRJR	255 200 JRJR	251 300 JRJR	255 300 JRJR	251 400 JRJR	255 400 JRJR
150 mA	251 100 JXJX	251 200 JXJX	255 200 JXJX	251 300 JXJX	255 300 JXJX	251 400 JXJX	255 400 JXJX
200 mA	251 100 KAKA	251 200 KAKA	255 200 KAKA	251 300 KAKA	255 300 KAKA	251 400 KAKA	255 400 KAKA
250 mA	251 100 KDKD	251 200 KDKD	255 200 KDKD	251 300 KDKD	255 300 KDKD	251 400 KDKD	255 400 KDKD
300 mA	251 100 KGKG	251 200 KGKG	255 200 KGKG	251 300 KGKG	255 300 KGKG	251 400 KGKG	255 400 KGKG
500 mA	251 100 KMKM	251 200 KMKM	255 200 KMKM	251 300 KMKM	255 300 KMKM	251 400 KMKM	255 400 KMKM
800 mA	251 100 KWKW	251 200 KWKW	255 200 KWKW	251 300 KWKW	255 300 KWKW	251 400 KWKW	255 400 KWKW
DC MILLIAMMETERS — ZERO-CENTER							
1-0-1 mA	251 101 FAFA	251 201 FAFA	255 201 FAFA	251 301 FAFA	255 301 FAFA	251 401 FAFA	255 401 FAFA
5-0-5 mA	251 101 FXFX	251 201 FXFX	255 201 FXFX	251 301 FXFX	255 301 FXFX	251 401 FXFX	255 401 FXFX
10-0-10 mA	251 101 GZGZ	251 201 GZGZ	255 201 GZGZ	251 301 GZGZ	255 301 GZGZ	251 401 GZGZ	255 401 GZGZ
20-0-20 mA	251 101 HFHF	251 201 HFHF	255 201 HFHF	251 301 HFHF	255 301 HFHF	251 401 HFHF	255 401 HFHF
25-0-25 mA	251 101 HJHJ	251 201 HJHJ	255 201 HJHJ	251 301 HJHJ	255 301 HJHJ	251 401 HJHJ	255 401 HJHJ
30-0-30 mA	251 101 HMHM	251 201 HMHM	255 201 HMHM	251 301 HMHM	255 301 HMHM	251 401 HMHM	255 401 HMHM
50-0-50 mA	251 101 HYHY	251 201 HYHY	255 201 HYHY	251 301 HYHY	255 301 HYHY	251 401 HYHY	255 401 HYHY
100-0-100 mA	251 101 JRJR	251 201 JRJR	255 201 JRJR	251 301 JRJR	255 301 JRJR	251 401 JRJR	255 401 JRJR
150-0-150 mA	251 101 JXJX	251 201 JXJX	255 201 JXJX	251 301 JXJX	255 301 JXJX	251 401 JXJX	255 401 JXJX
200-0-200 mA	251 101 KAKA	251 201 KAKA	255 201 KAKA	251 301 KAKA	255 301 KAKA	251 401 KAKA	255 401 KAKA
250-0-250 mA	251 101 KDKD	251 201 KDKD	255 201 KDKD	251 301 KDKD	255 301 KDKD	251 401 KDKD	255 401 KDKD
300-0-300 mA	251 101 KGKG	251 201 KGKG	255 201 KGKG	251 301 KGKG	255 301 KGKG	251 401 KGKG	255 401 KGKG
500-0-500 mA	251 101 KMKM	251 201 KMKM	255 201 KMKM	251 301 KMKM	255 301 KMKM	251 401 KMKM	255 401 KMKM
DC AMMETERS — ZERO-LEFT							
1 Amp	251 100 LALA	251 200 LALA	255 200 LALA	251 300 LALA	255 300 LALA	251 400 LALA	255 400 LALA
1.5 Amp	251 100 LCLC	251 200 LCLC	255 200 LCLC	251 300 LCLC	255 300 LCLC	251 400 LCLC	255 400 LCLC
2 Amp	251 100 LELE	251 200 LELE	255 200 LELE	251 300 LELE	255 300 LELE	251 400 LELE	255 400 LELE
13 Amp	251 100 LJLJ	251 200 LJLJ	255 200 LJLJ	251 300 LJLJ	255 300 LJLJ	251 400 LJLJ	255 400 LJLJ
5 Amp	251 100 LSLS	251 200 LSLS	255 200 LSLS	251 300 LSLS	255 300 LSLS	251 400 LSLS	255 400 LSLS
10 Amp	251 100 MTMT	251 200 MTMT	255 200 MTMT	251 300 MTMT	255 300 MTMT	251 400 MTMT	255 400 MTMT
15 Amp	.....	251 200 NDND	255 200 NDND	251 300 NDND	255 300 NDND	251 400 NDND	255 400 NDND
20 Amp	.....	251 200 NGNG	255 200 NGNG	251 300 NGNG	255 300 NGNG	251 400 NGNG	255 400 NGNG
30 Amp	.....	251 200 NLNL	255 200 NLNL	251 300 NLNL	255 300 NLNL	251 400 NLNL	255 400 NLNL
50 Amp	.....	251 200 NTNT	.....	251 300 NTNT	255 300 NTNT	251 400 NTNT	255 400 NTNT
DC AMMETERS — ZERO-LEFT, 50 mV, SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*							
20 Amp	251 124 ECNG	251 224 ECNG	255 224 ECNG	251 324 ECNG	255 324 ECNG	251 424 ECNG	255 424 ECNG
30 Amp	251 124 ECNL	251 224 ECNL	255 224 ECNL	251 324 ECNL	255 324 ECNL	251 424 ECNL	255 424 ECNL
50 Amp	251 124 ECNT	251 224 ECNT	255 224 ECNT	251 324 ECNT	255 324 ECNT	251 424 ECNT	255 424 ECNT
75 Amp	251 124 ECPB	251 224 ECPB	255 224 ECPB	251 324 ECPB	255 324 ECPB	251 424 ECPB	255 424 ECPB
100 Amp	251 124 ECPK	251 224 ECPK	255 224 ECPK	251 324 ECPK	255 324 ECPK	251 424 ECPK	255 424 ECPK
150 Amp	251 124 ECPZ	251 224 ECPZ	255 224 ECPZ	251 324 ECPZ	255 324 ECPZ	251 424 ECPZ	255 424 ECPZ
200 Amp	251 124 ECRL	251 224 ECRL	255 224 ECRL	251 324 ECRL	255 324 ECRL	251 424 ECRL	255 424 ECRL
250Amp	251 124 ECRS	251 224 ECRS	255 224 ECRS	251 324 ECRS	255 324 ECRS	251 424 ECRS	255 424 ECRS
300 Amp	251 124 ECRX	251 224 ECRX	255 224 ECRX	251 324 ECRX	255 324 ECRX	251 424 ECRX	255 424 ECRX
400 Amp	251 124 ECSC	251 224 ECSC	255 224 ECSC	251 324 ECSC	255 324 ECSC	251 424 ECSC	255 424 ECSC

SCALE ONLY

IP7014975

DC Ammeters Cont'd

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
DC AMMETERS — ZERO-LEFT, 50mV, SHUNT RATED* - continued							
SCALE ONLY							
500 Amp	251 124 ECSF	251 224 ECSF	255 224 ECSF	251 324 ECSF	255 324 ECSF	251 424 ECSF	255 424 ECSF
600 Amp	251 124 ECSJ	251 224 ECSJ	255 224 ECSJ	251 324 ECSJ	255 324 ECSJ	251 424 ECSJ	255 424 ECSJ
800 Amp	251 124 ECSN	251 224 ECSN	255 224 ECSN	251 324 ECSN	255 324 ECSN	251 424 ECSN	255 424 ECSN
1 Kilomap	251 124 ECVA	251 224 ECVA	255 224 ECVA	251 324 ECVA	255 324 ECVA	251 424 ECVA	255 424 ECVA
1.5 Kiloamp	251 124 ECVC	251 224 ECVC	255 224 ECVC	251 324 ECVC	255 324 ECVC	251 424 ECVC	255 424 ECVC
2 Kiloamp	251 124 ECVE	251 224 ECVE	255 224 ECVE	251 324 ECVE	255 324 ECVE	251 424 ECVE	255 424 ECVE
DC AMMETERS — ZERO-LEFT, 100mV, SHUNT RATED (LEAD RES. RANGE: .04-.08Ω)*							
SCALE ONLY							
20 Amp	251 124 GBNG	251 224 GBNG	255 224 GBNG	251 324 GBNG	255 324 GBNG	251 424 GBNG	255 424 GBNG
40 Amp	251 124 GBNP	251 224 GBNP	255 224 GBNP	251 324 GBNP	255 324 GBNP	251 424 GBNP	255 424 GBNP
50 Amp	251 124 GBNT	251 224 GBNT	255 224 GBNT	251 324 GBNT	255 324 GBNT	251 424 GBNT	255 424 GBNT
75 Amp	251 124 GBPB	251 224 GBPB	255 224 GBPB	251 324 GBPB	255 324 GBPB	251 424 GBPB	255 424 GBPB
100 Amp	251 124 GBPK	251 224 GBPK	255 224 GBPK	251 324 GBPK	255 324 GBPK	251 424 GBPK	255 424 GBPK
150 Amp	251 124 GBPZ	251 224 GBPZ	255 224 GBPZ	251 324 GBPZ	255 324 GBPZ	251 424 GBPZ	255 424 GBPZ
200 Amp	251 124 GBRL	251 224 GBRL	255 224 GBRL	251 324 GBRL	255 324 GBRL	251 424 GBRL	255 424 GBRL
250 Amp	251 124 GBRS	251 224 GBRS	255 224 GBRS	251 324 GBRS	255 324 GBRS	251 424 GBRS	255 424 GBRS
300 Amp	251 124 GBRX	251 224 GBRX	255 224 GBRX	251 324 GBRX	255 324 GBRX	251 424 GBRX	255 424 GBRX
400 Amp	251 124 GBSC	251 224 GBSC	255 224 GBSC	251 324 GBSC	255 324 GBSC	251 424 GBSC	255 424 GBSC
500 Amp	251 124 GBSF	251 224 GBSF	255 224 GBSF	251 324 GBSF	255 324 GBSF	251 424 GBSF	255 424 GBSF
600 Amp	251 124 GBSJ	251 224 GBSJ	255 224 GBSJ	251 324 GBSJ	255 324 GBSJ	251 424 GBSJ	255 424 GBSJ
800 Amp	251 124 GBSN	251 224 GBSN	255 224 GBSN	251 324 GBSN	255 324 GBSN	251 424 GBSN	255 424 GBSN
1 Kiloamp	251 124 GBVA	251 224 GBVA	255 224 GBVA	251 324 GBVA	255 324 GBVA	251 424 GBVA	255 424 GBVA
2 Kiloamp	251 124 GBVE	251 224 GBVE	255 224 GBVE	251 324 GBVE	255 324 GBVE	251 424 GBVE	255 424 GBVE
DC AMMETERS — ZERO-CENTER							
1-0-1 Amp	251 101 LALA	251 201 LALA	255 201 LALA	251 301 LALA	255 301 LALA	251 401 LALA	255 401 LALA
2-0-2 Amp	251 101 LELE	251 201 LELE	255 201 LELE	251 301 LELE	255 301 LELE	251 401 LELE	255 401 LELE
5-0-5Amp	251 101 LSLS	251 201 LSLS	255 201 LSLS	251 301 LSLS	255 301 LSLS	251 401 LSLS	255 401 LSLS
10-0-10 Amp	251 101 MTMT	251 201 MTMT	255 201 MTMT	251 301 MTMT	255 301 MTMT	251 401 MTMT	255 401 MTMT
15-0-15 Amp	.....	251 201 NDND	255 201 NDND	251 301 NDND	255 301 NDND	251 401 NDND	255 401 NDND
20-0-20 Amp	.....	251 201 NGNG	255 201 NGNG	251 301 NGNG	255 301 NGNG	251 401 NGNG	255 401 NGNG
30-0-30 Amp	.....	251 201 NLNL	255 201 NLNL	251 301 NLNL	255 301 NLNL	251 401 NLNL	255 401 NLNL
50-0-50 Amp	.....	.....	.....	251 301 NTNT	255 301 NTNT	251 401 NTNT	255 401 NTNT
DC AMMETERS — ZERO-CENTER, 50mV, SHUNT RATED (LEAD RES. RANGE .05-.07Ω)*							
SCALE ONLY							
20-0-20 Amp	251 125 ECNG	251 225 ECNG	255 225 ECNG	251 325 ECNG	255 325 ECNG	.....	.....
40-0-40 Amp	251 125 ECNP	251 225 ECNP	255 225 ECNP	251 325 ECNP	255 325 ECNP	251 425 ECNP	225 425 ECNP
50-0-50 Amp	251 125 ECNT	251 225 ECNT	255 225 ECNT	251 325 ECNT	255 325 ECNT	251 425 ECNT	225 425 ECNT
75-0-75 Amp	251 125 ECPB	251 225 ECPB	255 225 ECPB	251 325 ECPB	255 325 ECPB	251 425 ECPB	225 425 ECPB
100-0-100 Amp	251 125 ECPK	251 225 ECPK	255 225 ECPK	251 325 ECPK	255 325 ECPK	251 425 ECPK	225 425 ECPK

*Shunts are not included: For 50mV shunts, see page 29

AC Voltmeters

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
AC VOLTMETERS — SELF-CONTAINED, IRON VANE TYPE, 60 Hz							
3 Volts	.....	.....	251 244 LJLJ	.....	251 344 LJLJ	.....	251 444 LJLJ
5 Volts	.....	.....	251 244 LSLS	.....	251 344 LSLS	.....	251 444 LSLS
10 Volts	.....	.....	251 244 MTMT	.....	251 344 MTMT	.....	251 444 MTMT
15 Volts	.....	.....	251 244 NDND	.....	251 344 NDND	.....	251 444 NDND
30 Volts	.....	.....	251 244 NLNL	.....	251 344 NLNL	.....	251 444 NLNL
50 Volts	.....	.....	251 244 NTNT	.....	251 344 NTNT	.....	251 444 NTNT
150 Volts	.....	.....	251 244 PZPZ	.....	251 344 PZPZ	.....	251 444 PZPZ
300 Volts	.....	.....	251 244 RXRX	.....	251 344 RXRX	.....	251 444 RXRX
500 Volts	.....	.....	.....	.....	251 344 SFSF	.....	251 444 SFSF
600 Volts	.....	.....	.....	.....	251 344 SJSJ	.....	251 444 SJSJ

AC Voltmeters Cont'd

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
AC VOLTMETERS — SELF-CONTAINED, IRON VANE TYPE, 400 Hz							
150 Volts	.....	.....	251 245 PZPZ	.....	251 345 PZPZ	.....	251 445 PZPZ
300 Volts	.....	.....	251 245 RXRX	.....	251 345 RXRX	.....	251 445 RXRX
AC VOLTMETERS — TRANSFORMER RATED, 0-150 VOLTS, IRON VANE TYPE, 60 Hz. (See Page 29 For Transformers)							
SCALE ONLY							
600 Volts	.....	.....	251 244 PZSJ	.....	251 344 PZSJ	.....	251 444 PZSJ
750 Volts	.....	.....	251 244 PZSM	.....	251 344 PZSM	.....	251 444 PZSM
3 kV	.....	.....	251 244 PZVJ	.....	251 344 PZVJ	.....	251 444 PZVJ
AC VOLTMETERS — EXPANDED SCALE, RECTIFIER TYPE							
110-130 Volts	.....	.....	.....	251 337 PNPN	255 337 PNPN	251 437 PNPN	255 437 PNPN
105-125 Volts	.....	.....	.....	251 337 PTPT	255 337 PTPT	251 437 PTPT	255 437 PTPT
AC VOLTMETERS — SELF-CONTAINED, RECTIFIER TYPE							
10 Volts	251 130 MTMT	251 230 MTMT	255 230 MTMT	251 330 MTMT	255 330 MTMT	251 430 MTMT	255 430 MTMT
15 Volts	251 130 NDND	251 230 NDND	255 230 NDND	251 330 NDND	255 330 NDND	251 430 NDND	255 430 NDND
20 Volts	251 130 NGNG	251 230 NGNG	255 230 NGNG	251 330 NGNG	255 330 NGNG	251 430 NGNG	255 430 NGNG
25 Volts	251 130 NJNJ	251 230 NJNJ	255 230 NJNJ	251 330 NJNJ	255 330 NJNJ	251 430 NJNJ	255 430 NJNJ
30 Volts	251 130 NLNL	251 230 NLNL	255 230 NLNL	251 330 NLNL	255 330 NLNL	251 430 NLNL	255 430 NLNL
50 Volts	251 130 NTNT	251 230 NTNT	255 230 NTNT	251 330 NTNT	255 330 NTNT	251 430 NTNT	255 430 NTNT
80 Volts	251 130 PDPD	251 230 PDPD	255 230 PDPD	251 330 PDPD	255 330 PDPD	251 430 PDPD	255 430 PDPD
100 Volts	251 130 PKPK	251 230 PKPK	255 230 PKPK	251 330 PKPK	255 330 PKPK	251 430 PKPK	255 430 PKPK
150 Volts	251 130 PZPZ	251 230 PZPZ	255 230 PZPZ	251 330 PZPZ	255 330 PZPZ	251 430 PZPZ	255 430 PZPZ
200 Volts	.....	.....	.....	251 330 RLRL	255 330 RLRL	251 430 RLRL	255 430 RLRL
250 Volts	.....	.....	.....	251 330 RSRS	255 330 RSRS	251 430 RSRS	255 430 RSRS
300 Volts	.....	.....	.....	251 330 RXRX	255 330 RXRX	251 430 RXRX	255 430 RXRX

AC Ammeters

Size	1½	2½		3½		4½	
Rating & Scale / Type	Taut Band	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel	Taut Band	Pivot and Jewel
AC MICROAMMETERS AND MILLIAMMETERS — RECTIFIER TYPE							
500 µA	251 110 EMEM	251 210 EMEM	255 210 EMEM	251 310 EMEM	255 310 EMEM	251 410 EMEM	255 410 EMEM
800 µA	251 110 EWEW	251 210 EWEW	255 210 EWEW	251 310 EWEW	255 310 EWEW	251 410 EWEW	255 410 EWEW
1 mA	251 110 FAFA	251 210 FAFA	255 210 FAFA	251 310 FAFA	255 310 FAFA	251 410 FAFA	255 410 FAFA
1.5 mA	251 110 FDFD	251 210 FDFD	255 210 FDFD	251 310 FDFD	255 310 FDFD	251 410 FDFD	255 410 FDFD
2 mA	251 110 FGFG	251 210 FGFG	255 210 FGFG	251 310 FGFG	255 310 FGFG	251 410 FGFG	255 410 FGFG
3 mA	251 110 FNFN	251 210 FNFN	255 210 FNFN	251 310 FNFN	255 310 FNFN	251 410 FNFN	255 410 FNFN
5 mA	251 110 FXFX	251 210 FXFX	255 210 FXFX	251 310 FXFX	255 310 FXFX	251 410 FXFX	255 410 FXFX
10 mA	251 110 GZGZ	251 210 GZGZ	255 210 GZGZ	251 310 GZGZ	255 310 GZGZ	251 410 GZGZ	255 410 GZGZ
20 mA	251 110 HFHF	251 210 HFHF	255 210 HFHF	251 310 HFHF	255 310 HFHF	251 410 HFHF	255 410 HFHF

AC Ammeters Cont'd

AC MILLIAMMETERS — SELF-CONTAINED, 25-400 Hz, IRON VANE

10 mA			251 240 GZGZ		251 340 GZGZ		251 440 GZGZ
25 mA			251 240 HJHJ		251 340 HJHJ		251 440 HJHJ
50 mA			251 240 HYHY		251 340 HYHY		251 440 HYHY
100 mA			251 240 JRJR		251 340 JRJR		251 440 JRJR
200 mA			251 240 KAKA		251 340 KAKA		251 440 KAKA
500 mA			251 240 KMKM		251 340 KMKM		251 440 KMKM

AC AMMETERS — SELF-CONTAINED, 25-400 Hz, IRON VANE

1 Amp			251 240 LALA		251 340 LALA		251 440 LALA
3 Amp			251 240 LJLJ		251 340 LJLJ		251 440 LJLJ
5 Amp			251 240 LSLS		251 340 LSLS		251 440 LSLS
8 Amp			251 240 MJMJ		251 340 MJMJ		251 440 MJMJ
10 Amp			251 240 MTMT		251 340 MTMT		251 440 MTMT
15 Amp			251 240 NDND		251 340 NDND		251 440 NDND
20 Amp			251 240 NGNG*		251 340 NGNG*		251 440 NGNG*
30 Amp			251 240 NLNL*		251 340 NLNL*		251 440 NLNL*
50 Amp					251 340 NTNT*		251 440 NTNT*
80 Amp					251 340 PDPD*		251 440 PDPD*

*External magnetic shield included

AC AMMETERS — TRANSFORMER-RATED, 0-5 AMPERES, 25-400 Hz, IRON VANE (See Page 29 For Transformers)

10 Amp			251 240 LSMT		251 340 LSMT		251 440 LSMT
15 Amp			251 240 LSND		251 340 LSND		251 440 LSND
20 Amp			251 240 LSNG		251 340 LSNG		251 440 LSNG
30 Amp			251 240 LSNL		251 340 LSNL		251 440 LSNL
40 Amp			251 240 LSNP		251 340 LSNP		251 440 LSNP
50 Amp			251 240 LSNT		251 340 LSNT		251 440 LSNT
75 Amp			251 240 LSPB		251 340 LSPB		251 440 LSPB
80 Amp			251 240 LSPD		251 340 LSPD		251 440 LSPD
100 Amp			251 240 LSPK		251 340 LSPK		251 440 LSPK
150 Amp			251 240 LSPZ		251 340 LSPZ		251 440 LSPZ
200 Amp			251 240 LSRL		251 340 LSRL		251 440 LSRL
300 Amp			251 240 LSRX		251 340 LSRX		251 440 LSRX
400 Amp			251 240 LSSC		251 340 LSSC		251 440 LSSC
500 Amp			251 240 LSSF		251 340 LSSF		251 440 LSSF
600 Amp			251 240 LSSJ		251 340 LSSJ		251 440 LSSJ
800 Amp			251 240 LSSN		251 340 LSSN		251 440 LSSN
1 Kiloamp			251 240 LSVA		251 340 LSVA		251 440 LSVA
1.2 Kiloamp			251 240 LSVB		251 340 LSVB		251 440 LSVB
1.5 Kiloamp			251 240 LSVC		251 340 LSVC		251 440 LSVC
2.0 Kiloamp			251 240 LSVE		251 340 LSVE		251 440 LSVE
3.0 Kiloamp			251 240 LSVJ		251 340 LSVJ		251 440 LSVJ

SCALE ONLY

AC Motor Load Indicators - Available in Horizon Line or New Big Look

	Size		2½	3½	4½
Rating Amps	Scale Marking	Terminal Resistance Ohms (±15%)	Cat. No.	Cat. No.	Cat. No.

AC LOAD INDICATORS, PIVOT AND JEWEL TYPE 250 — 5-AMP CURRENT TRANSFORMER RATED, 60 Hz — IRON VANE TYPE

5	0-150% Motor Load Current Red Band — 100-150	0.007	250 240 LSPZ7AAA	250 340 LSPZ7AAA	250 440 LSPZ7AAA
5	0-150% Motor Load Current Green — 0-100 Yellow — 100-125, Red — 125-150	0.007	250 240 LSPZ7AAB	250 340 LSPZ7AAB	250 440 LSPZ7AAB

AC LOAD INDICATORS, PIVOT AND JEWEL TYPE 251 — 5-AMP CURRENT TRANSFORMER RATED, 60 Hz — IRON VANE TYPE

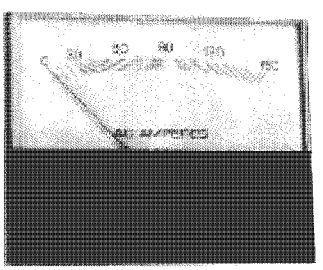
5	0-150% Motor Load Current Red Band — 100-150	0.007	251 240 LSPZ7AAJ	251 340 LSPZ7AAJ	251 440 LSPZ7AAJ
5	0-150% Motor Load Current Green — 0-100 Yellow — 100-125, Red — 125-150	0.007	251 240 LSPZ7AAK	251 340 LSPZ7AAK	251 440 LSPZ7AAK

AC Frequency Meters - Available in Horizon Line or New Big Look

Size			1½	2½	3½	4½
Voltage	Center Frequency Hertz	Scale Hertz	Cat. No.	Cat. No.	Cat. No.	Cat. No.
AC FREQUENCY — PIVOT AND JEWEL, SELF-CONTAINED, ACCURACY ±3 PERCENT OF SPAN; I.E., 0.3 Hz FOR 45-55 AND 55-65, AND 1.2 Hz FOR 380-420 RANGE						
120	50	45-55	.....	Choose prefix 254 or 255: 250 AGAG	Choose prefix 254 or 255: 350 AGAG	Choose prefix 254 or 255: 450 AGAG
120	55	45-65	.....	250 AJAJ	350 AJAJ	450 AJAJ
120	60	55-65	.....	250 ANAN	350 ANAN	450 ANAN
120	400	380-420	.....	250 BKBK	350 BKBK	450 BKBK
208	50	45-55	.....	250 GGGG	350 GGGG	450 GGGG
208	55	45-65	.....	250 GJGJ	350 GJGJ	450 GJGJ
208	60	55-65	.....	250 GNGN	350 GNGN	450 GNGN
208	400	380-420	.....	250 HKHK	350 HKHK	450 HKHK
240	50	45-55	.....	250 DGDG	350 DGDG	450 DGDG
240	55	45-65	.....	250 DJDJ	350 DJDJ	450 DJDJ
240	60	55-65	.....	250 DNDN	350 DNDN	450 DNDN
240	400	380-420	.....	250 EKEK	350 EKEK	450 EKEK

NOTE: For non-listed voltages, up to 480 VAC, frequency ranges or special calibration (accuracy ±2% of span) contact factory. For taut-band suspension replace prefix 254 with 250 and prefix 255 with 251.

YOKOGAWA ◆ Stylist Series



Type 260 and 264
Stylist Surface Mount

Specifications

Accuracy: All DC and AC iron vane, ±2% of fullscale, AC rectifier type; ±3% of fullscale (60 Hz sinewave). Expanded scale voltmeters ±5% of fullscale. Special order DC with mirror back scale (DC only) 31/2 - 41/2" Available @ ±1%.

ANSI Specification: All meters meet ANSI Specifications C-39.1 (See page 14 for exceptions.)

Overload: Voltmeters (AC + DC) - 50% momentary, 20% sustained. Ammeters (AC +DC) momentary: 10 times the rated current for 10 consecutive intervals of .5 seconds with 1 minute interval between successive applications; sustained: 20% for six hours.

Scale Data:

ARC	90%	95%
METER SIZE	AC IRON VANE	TAUT BAND/ PIVOT & JEWEL
1½"	—	1.66"
2½"	2.15"	2.29"
3½"	2.70"	2.85"
4½"	3.80"	4.01"

Insulation Level: 2600V/1 min. (2½"-4½")
1500V/1 min. (1½")

Response Time:
3 seconds (Max.) - Microammeters
2 seconds (Max.) - All other DC ratings
2.5 seconds (Max.) - All AC ratings
Maximum 40% overshoot

Dimensions: See page 36.

Burden Data: AC Ammeter 5 amps @ 60 Hz, 0.5VA, Max. .5 Power factor lagging, AC voltmeter - unity power factor.

Notes:
Severe-duty meters are available to meet CSA or UL 1437 requirements in 2½"-4½" sizes. To order, add /UL or /CSA after catalog number, or contact factory.

DC Voltmeters

Rating & Scale \ Size	1½	2½	3½	4½
DC MILLIVOLTMETERS — ZERO-LEFT				
0-50	260124ECEC	26□224ECEC	26□324ECEC	26□424ECEC
0-100	260124GBGB	26□224GBGB	26□324GBGB	26□424GBGB
DC MILLIVOLTMETERS — ZERO-CENTER				
50-0-50	260125ECEC	26□225ECEC	26□325ECEC	26□425ECEC
100-0-100	260125GBGB	26□225GBGB	26□325GBGB	26□425GBGB
DC VOLTMETERS — ZERO-LEFT				
0-1	260120LALA	26□220LALA	26□320LALA	26□420LALA
0-1.5	260120LCLC	26□220LCLC	26□320LCLC	26□420LCLC
0-2	260120LELE	26□220LELE	26□320LELE	26□420LELE
0-3	260120LJLJ	26□220LJLJ	26□320LJLJ	26□420LJLJ
0-5	260120LSLS	26□220LSLS	26□320LSLS	26□420LSLS
0-10	260120MTMT	26□220MTMT	26□320MTMT	26□420MTMT
0-15	260120NDND	26□220NDND	26□320NDND	26□420NDND
0-20	260120NGNG	26□220NGNG	26□320NGNG	26□420NGNG
0-25	260120NJNJ	26□220NJNJ	26□320NJNJ	26□420NJNJ
0-30	260120NLNL	26□220NLNL	26□320NLNL	26□420NLNL
0-40	260120NPNP	26□220NPNP	26□320NPNP	26□420NPNP
0-50	260120NTNT	26□220NTNT	26□320NTNT	26□420NTNT
0-75	260120PBPB	26□220PBPB	26□320PBPB	26□420PBPB
0-80	260120PDPD	26□220PDPD	26□320PDPD	26□420PDPD
0-100	260120PKPK	26□220PKPK	26□320PKPK	26□420PKPK
0-150	260120PZPZ	26□220PZPZ	26□320PZPZ	26□420PZPZ
0-200	260120RLRL	26□220RLRL	26□320RLRL	26□420RLRL
0-250	260120RSRS	26□220RSRS	26□320RSRS	26□420RSRS
0-300	260120RXRX	26□220RXRX	26□320RXRX	26□420RXRX
* 0-500	260120SFSF	26□220SFSF	26□320SFSF	26□420SFSF
* 0-600	260120SJSJ	26□220SJSJ	26□320SJSJ	26□420SJSJ
* 0-750	260120SMSM	26□220SMSM	26□320SMSM	26□420SMSM
* 0-1000	260120SSSS	26□220SSSS	26□320SSSS	26□420SSSS
DC VOLTMETERS — ZERO-CENTER				
5-0-5	260121LSLS	26□221LSLS	26□321LSLS	26□421LSLS
10-0-10	260121MTMT	26□221MTMT	26□321MTMT	26□421MTMT
15-0-15	260121NDND	26□221NDND	26□321NDND	26□421NDND
25-0-25	260121NJNJ	26□221NJNJ	26□321NJNJ	26□421NJNJ
50-0-50	260121NTNT	26□221NTNT	26□321NTNT	26□421NTNT
100-0-100	260121PKPK	26□221PKPK	26□321PKPK	26□421PKPK
150-0-150	260121PZPZ	26□221PZPZ	26□321PZPZ	26□421PZPZ
300-0-300	260121RXRX	26□221RXRX	26□321RXRX	26□421RXRX
* 500-0-500	260121SFSF	26□221SFSF	26□321SFSF	26□421SFSF
* 600-0-600	260121SJSJ	26□221SJSJ	26□321SJSJ	26□421SJSJ
DC VOLTMETERS — EXPANDED SCALE				
5 ± 10%		26□238LYLY	26□338LYLY	26□438LYLY
12 ± 10%		26□238MYMY	26□338MYMY	26□438MYMY
15 ± 10%		26□238NFNF	26□338NFNF	26□438NFNF
28 ± 10%		26□238NHNH	26□338NHNH	26□438NHNH
48 ± 10%		26□238NSNS	26□338NSNS	26□438NSNS
120 ± 10%		26□238PPPP	26□338PPPP	26□438PPPP
150 ± 10%		26□238PYPY	26□338PYPY	26□438PYPY
300 ± 10%		26□238RWRW	26□338RWRW	26□438RWRW
DC VOLTMETERS — PERCENT DEVIATION ±.05% FULL SCALE ACCURACY				
12 ± 10%		26□221MYMY	26□321MYMY	26□421MYMY
28 ± 10%		26□221NHNH	26□321NHNH	26□421NHNH
120 ± 10%		26□221PPPP	26□321PPPP	26□421PPPP

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*Not ANSI.

DC Ammeters

Rating & Scale \ Size	1½	2½	3½	4½
DC MICROAMMETERS — ZERO-LEFT				
0-10	260100BZBZ	26□200BZBZ*	26□300BZBZ*	26□400BZBZ*
0-20	260100CFCF	26□200CFCF*	26□300CFCF*	26□400CFCF*
0-50	260100CYCY	26□200CYCY	26□300CYCY	26□400CYCY
0-100	260100DRDR	26□200DRDR	26□300DRDR	26□400DRDR
0-200	260100EAEA	26□200EAEA	26□300EAEA	26□400EAEA
0-500	260100EMEM	26□200EMEM	26□300EMEM	26□400EMEM
DC MICROAMMETERS — ZERO-CENTER				
10-0-105	260101BZBZ	26□201BZBZ*	26□301BZBZ*	26□401BZBZ*
25-0-25	260101CJCJ	26□201CJCJ	26□301CJCJ	26□401CJCJ
50-0-50	260101CYCY	26□201CYCY	26□301CYCY	26□401CYCY
100-0-100	260101DRDR	26□201DRDR	26□301DRDR	26□401DRDR
500-0-500	260101EMEM	26□201EMEM	26□301EMEM	26□401EMEM
DC MILLIAMMETEERS — ZERO-LEFT				
0-1	260100FAFA	26□200FAFA	26□300FAFA	26□400FAFA
0-2	260100FGFG	26□200FGFG	26□300FGFG	26□400FGFG
0-3	260100FNFN	26□200FNFN	26□300FNFN	26□400FNFN
0-5	260100FXFX	26□200FXFX	26□300FXFX	26□400FXFX
0-10	260100GZGZ	26□200GZGZ	26□300GZGZ	26□400GZGZ
0-15	260100HCHC	26□200HCHC	26□300HCHC	26□400HCHC
0-20	260100HFHF	26□200HFHF	26□300HFHF	26□400HFHF
0-25	260100HJHJ	26□200HJHJ	26□300HJHJ	26□400HJHJ
0-30	260100HMHM	26□200HMHM	26□300HMHM	26□400HMHM
0-50	260100HYHY	26□200HYHY	26□300HYHY	26□400HYHY
0-100	260100JRJR	26□200JRJR	26□300JRJR	26□400JRJR
0-150	260100JXJX	26□200JXJX	26□300JXJX	26□400JXJX
0-200	260100KAKA	26□200KAKA	26□300KAKA	26□400KAKA
0-300	260100KGKG	26□200KGKG	26□300KGKG	26□400KGKG
0-500	260100KMKM	26□200KMKM	26□300KMKM	26□400KMKM
0-750	260100KUKU	26□200KUKU	26□300KUKU	26□400KUKU
DC MILLIAMMETERS — ZERO-CENTER				
1-0-1	260101FAFA	26□201FAFA	26□301FAFA	26□401FAFA
5-0-5	260101FXFX	26□201FXFX	26□301FXFX	26□401FXFX
10-0-10	260101GZGZ	26□201GZGZ	26□301GZGZ	26□401GZGZ
25-0-25	260101HJHJ	26□201HJHJ	26□301HJHJ	26□401HJHJ
50-0-50	260101HYHY	26□201HYHY	26□301HYHY	26□401HYHY
100-0-100	260101JRJR	26□201JRJR	26□301JRJR	26□401JRJR
200-0-200	260101KAKA	26□201KAKA	26□301KAKA	26□401KAKA
500-0-500	260101KMKM	26□201KMKM	26□301KMKM	26□401KMKM
DC MILLIAMMETERS — SUPPRESSED ZERO (Indicating receiving gauge applications ±3% F.S.)				
0.25-1.25	260100FEFE	26□200FEFE	26□300FEFE	26□400FEFE
1-5	260100FYFY	26□200FYFY	26□300FYFY	26□400FYFY
4-20	260100HEHE	26□200HEHE	26□300HEHE	26□400HEHE
10-50	260100HXHX	26□200HXHX	26□300HXHX	26□400HXHX

These meters are supplied with 0-100 dial labeled PERCENT.

DC AMMETERS — ZERO-LEFT, SELF-CONTAINED				
0-1	260100LALA	26□200LALA	26□300LALA	26□400LALA
0-1.5	260100LCLC	26□200LCLC	26□300LCLC	26□400LCLC
0-2	260100LELE	26□200LELE	26□300LELE	26□400LELE
0-3	260100LJLJ	26□200LJLJ	26□300LJLJ	26□400LJLJ
0-5	260100LSLS	26□200LSLS	26□300LSLS	26□400LSLS
0-10	260100MTMT	26□200MTMT	26□300MTMT	26□400MTMT
0-15	—	26□200NDND	26□300NDND	26□400NDND
0-20	—	26□200NGNG	26□300NGNG	26□400NGNG

*Taut Band Only

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DC Ammeters Cont'd

DC AMMETERS — ZERO-LEFT, SELF-CONTAINED (cont'd)

Rating & Scale \ Size	1½	2½	3½	4½
0-25	—	26□200NJNJ	26□300NJNJ	26□400NJNJ
0-30	—	26□200NLNL	26□300NLNL	26□400NLNL
0-50	—	26□200NTNT	26□300NTNT	26□400NTNT

DC AMMETERS — ZERO-LEFT ,50mV SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*

Rating & Scale \ Size	1½	2½	3½	4½
0-15	260124ECND	26□224ECND	26□324ECND	26□424ECND
0-20	260124ECNG	26□224ECNG	26□324ECNG	26□424ECNG
0-25	260124ECNJ	26□224ECNJ	26□324ECNJ	26□424ECNJ
0-30	260124ECNL	26□224ECNL	26□324ECNL	26□424ECNL
0-50	260124ECNT	26□224ECNT	26□324ECNT	26□424ECNT
0-75	260124ECPB	26□224ECPB	26□324ECPB	26□424ECPB
SCALE ONLY 0-100	260124ECPK	26□224ECPK	26□324ECPK	26□424ECPK
0-150	260124ECPZ	26□224ECPZ	26□324ECPZ	26□424ECPZ
0-200	260124ECRL	26□224ECRL	26□324ECRL	26□424ECRL
0-300	260124ECRX	26□224ECRX	26□324ECRX	26□424ECRX
0-500	260124ECSF	26□224ECSF	26□324ECSF	26□424ECSF
0-750	260124ECSM	26□224ECSM	26□324ECSM	26□424ECSM
0-1000	260124ECSS	26□224ECSS	26□324ECSS	26□424ECSS
0-1200	260124ECSV	26□224ECSV	26□324ECSV	26□424ECSV
0-1500	260124ECTC	26□224ECTC	26□324ECTC	26□424ECTC
0-2000	260124ECTM	26□224ECTM	26□324ECTM	26□424ECTM

DC AMMETERS — ZERO LEFT, 100mV SHUNT RATED (LEAD RES. RANGE: 0.4-0.8Ω)*

Rating & Scale \ Size	1½	2½	3½	4½
0-75	260124GBPB	26□224GBPB	26□324GBPB	26□424GBPB
0-100	260124GBPK	26□224GBPK	26□324GBPK	26□424GBPK
0-150	260124GBPZ	26□224GBPZ	26□324GBPZ	26□424GBPZ
0-200	260124GBRL	26□224GBRL	26□324GBRL	26□424GBRL
0-300	260124GBRX	26□224GBRX	26□324GBRX	26□424GBRX
0-500	260124GBSF	26□224GBSF	26□324GBSF	26□424GBSF
SCALE ONLY 0-750	260124GBSM	26□224GBSM	26□324GBSM	26□424GBSM
0-1000	260124GBSS	26□224GBSS	26□324GBSS	26□424GBSS
0-1200	260124GBSV	26□224GBSV	26□324GBSV	26□424GBSV
0-1500	260124GBTC	26□224GBTC	26□324GBTC	26□424GBTC
0-2000	260124GBTM	26□224GBTM	26□324GBTM	26□424GBTM

DC AMMETERS — ZERO-CENTER, SELF-CONTAINED

Rating & Scale \ Size	1½	2½	3½	4½
1-0-1	260101LALA	26□201LALA	26□301LALA	26□401LALA
3-0-3	260101LJLJ	26□201LJLJ	26□301LJLJ	26□401LJLJ
5-0-5	260101LSLS	26□201LSLS	26□301LSLS	26□401LSLS
10-0-10	260101MTMT	26□201MTMT	26□301MTMT	26□401MTMT
15-0-15	—	26□201NDND	26□301NDND	26□401NDND
25-0-25	—	26□201NJNJ	26□301NJNJ	26□401NJNJ
50-0-50	—	26□201NTNT	26□301NTNT	26□401NTNT

DC AMMETERS — ZER0-CENTER, 50mV, SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*

Rating & Scale \ Size	1½	2½	3½	4½
15-0-15	260125ECND	26□225ECND	26□325ECND	26□425ECND
25-0-25	260125ECNJ	26□225ECNJ	26□325ECNJ	26□425ECNJ
50-0-50	260125ECNT	26□225ECNT	26□325ECNT	26□425ECNT
SCALE ONLY 75-0-75	260125ECPB	26□225ECPB	26□325ECPB	26□425ECPB
100-0-100	260125ECPK	26□225ECPK	26□325ECPK	26□425ECPK
200-0-200	260125ECRL	26□225ECRL	26□325ECRL	26□425ECRL
300-0-300	260125ECRX	26□225ECRX	26□325ECRX	26□425ECRX
400-0-400	260125ECSC	26□225ECSC	26□325ECSC	26□425ECSC
500-0-500	260125ECSF	26□225ECSF	26□325ECSF	26□425ECSF

*Shunts are not included. See Page 29 For 50mV Shunts.

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AC Voltmeters

Rating & Scale \ Size	1½	2½	3½	4½
AC VOLTMETERS — TAUT BAND, MOVING COIL: SELF-CONTAINED, RECTIFIER TYPE				
0-3	260130LJLJ	26□230LJLJ	26□330LJLJ	26□430LJLJ
0-5	260130LSLS	26□230LSLS	26□330LSLS	26□430LSLS
0-10	260130MTMT	26□230MTMT	26□330MTMT	26□430MTMT
0-15	260130NDND	26□230NDND	26□330NDND	26□430NDND
0-25	260130NJNJ	26□230NJNJ	26□330NJNJ	26□430NJNJ
0-50	260130NTNT	26□230NTNT	26□330NTNT	26□430NTNT
0-100	260130PKPK	26□230PKPK	26□330PKPK	26□430PKPK
0-150	260130PZPZ	26□230PZPZ	26□330PZPZ	26□430PZPZ
0-300	260130RXRX	26□230RXRX	26□330RXRX	26□430RXRX
0-500	260130SFSF	26□230SFSF	26□330SFSF	26□430SFSF
0-600	260130SJSJ	26□230SJSJ	26□330SJSJ	26□430SJSJ
AC VOLTMETERS — TAUT BAND, MOVING COIL: TRANSFORMER RATED, 0-150V, RECTIFIER TYPE*				
SCALE ONLY 0-750	260130PZSM	26□230PZSM	26□330PZSM	26□430PZSM
0-1500	260130PZTC	26□230PZTC	26□330PZTC	26□430PZTC
0-3000	260130PZUA	26□230PZUA	26□330PZUA	26□430PZUA
AC VOLTMETERS — TAUT BAND, MOVING COIL: EXPANDED SCALE, RECTIFIER TYPE				
	Accuracy			
105-125	±0.5%FS	26□237PTPT	26□337PTPT	26□437PTPT
210-250	±0.5%FS	26□237RRRR	26□337RRRR	26□437RRRR
95-135	±1.0%FS	26□237PJPJ	26□337PJPJ	26□437PJPJ
190-270	±1.0%FS	26□237RKRK	26□337RKRK	26□437RKRK
AC VOLTMETERS — IRON VANE, PIVOT & JEWEL: SELF-CONTAINED, 60Hz*				
0-500		26□244LJLJ	26□344LJLJ	26□444LJLJ
0-5		26□244LSLS	26□344LSLS	26□444LSLS
0-10		26□244MTMT	26□344MTMT	26□444MTMT
0-15		26□244NDND	26□344NDND	26□444NDND
0-30		26□244NLNL	26□344NLNL	26□444NLNL
0-50		26□244NTNT	26□344NTNT	26□444NTNT
0-100		26□244PKPK	26□344PKPK	26□444PKPK
0-150		26□244PZPZ	26□344PZPZ	26□444PZPZ
0-300		26□244RXRX	26□344RXRX	26□444RXRX
0-500		26□244SFSF	26□344SFSF	26□444SFSF
0-600		26□244SJSJ	26□344SJSJ	26□444SJSJ
AC VOLTMETERS — IRON VANE, PIVOT & JEWEL: TRANSFORMER RATED 0-150 VOLTS, 60Hz*				
SCALE ONLY 0-600		26□244PZSJ	26□344PZSJ	26□444PZSJ
0-750		26□244PZSM	26□344PZSM	26□444PZSM
0-3K		26□244PZVJ	26□344PZVJ	26□444PZVJ

*Iron Vane, Pivot & Jewel use only 0 for Surface Mount, 1 for Window Mount. Also, For Transformer Rated Voltmeters See Page 29 For Transformers.

AC Ammeters

Rating & Scale \ Size	1½	2½	3½	4½
AC MILLIAMMETERS — TAUT BAND, MOVING COIL: SELF-CONTAINED, RECTIFIER TYPE				
0-1	260110FAFA	26□210FAFA	26□310FAFA	26□410FAFA
0-5	260110FXFX	26□210FXFX	26□310FXFX	26□410FXFX
0-10	260110GZGZ	26□210GZGZ	26□310GZGZ	26□410GZGZ
0-25	260110HJHJ	26□210HJHJ	26□310HJHJ	26□410HJHJ
0-50	260110HYHY	26□210HYHY	26□310HYHY	26□410HYHY
0-100	260110JRJR	26□210JRJR	26□310JRJR	26□410JRJR
0-200	—	26□210KAKA	26□310KAKA	26□410KAKA

□ See page 18 for notes on ordering.

AC Ammeters Cont'd

AC AMMETERS — TAUT BAND, MOVING COIL: SELF-CONTAINED, RECTIFIER TYPE, 60Hz±10%

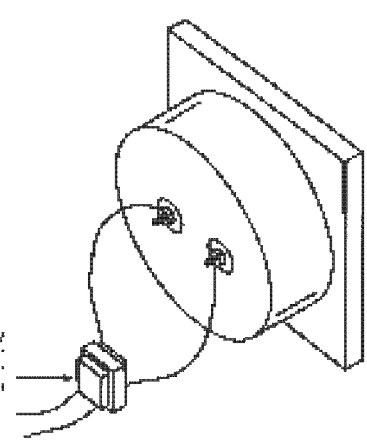
Rating & Scale \ Size	1½	2½	3½	4½
0-1		26□210LALA	26□310LALA	26□410LALA
0-1.5		26□210LCLC	26□310LCLC	26□410LCLC
0-2		26□210LELE	26□310LELE	26□410LELE
0-3		26□210LJLJ	26□310LJLJ	26□410LJLJ
0-5		26□210LSLS	26□310LSLS	26□410LSLS
0-10		26□210MTMT	26□310MTMT	26□410MTMT
0-15		26□210NDND	26□310NDND	26□410NDND
0-20		26□210NGNG	26□310NGNG	26□410NGNG
0-25		26□210NJNJ	26□310NJNJ	26□410NJNJ
0-30		26□210NLNL	26□310NLNL	26□410NLNL

AC AMMETERS — TAUT BAND, MOVING COIL: TRANSFORMER RATED, 0-5A, RECTIFIER TYPE, 60Hz±10%

0-50		26□210LSNT	26□310LSNT	26□410LSNT
0-60		26□210LSNW	26□310LSNW	26□410LSNW
0-75		26□210LSPB	26□310LSPB	26□410LSPB
0-100		26□210LSPK	26□310LSPK	26□410LSPK
0-150		26□210LSPZ	26□310LSPZ	26□410LSPZ
0-200		26□210LSRL	26□310LSRL	26□410LSRL
SCALE ONLY 0-300		26□210LSRX	26□310LSRX	26□410LSRX
0-400		26□210LSSC	26□310LSSC	26□410LSSC
0-500		26□210LSSF	26□310LSSF	26□410LSSF
0-600		26□210LSSJ	26□310LSSJ	26□410LSSJ
0-800		26□210LSSN	26□310LSSN	26□410LSSN
0-1000		26□210LSSS	26□310LSSS	26□410LSSS
0-1500		26□210LSTC	26□310LSTC	26□410LSTC
0-2000		26□210LSTM	26□310LSTM	26□410LSTM

AC AMMETERS — TAUT BAND, MOVING COIL: SEPARATE TRANSFORMERS, RECTIFIER TYPE, 60Hz±10%

0-1	260110LALA	EACH METER IS SUPPLIED WITH AN EXTERNAL C.T. WITH INPUT RANGE MATCHING FULL SCALE INPUT.
0-1.5	260110LCLC	
0-2	260110LELE	
0-3	260110LJLJ	
0-5	260110LSLS	
0-10	260110MTMT	
0-15	260110NDND	
0-20	260110NGNG	
0-25	260110NJNJ	
0-30	260110NLNL	
0-50	260110LSNT	METER SUPPLIED WITH 5 AMP EXTERNAL C.T. — USER MUST PURCHASE ADDITIONAL C.T. OF PROPER SCALE RANGE WITH 5 AMP SECONDARY TO CONNECT TO EXT. 5 AMP C.T. SUPPLIED, SEE CATALOG 500 CTPT.
0-60	260110LSNW	
0-75	260110LSPB	
0-100	260110LSPK	
0-150	260110LSPZ	
SCALE ONLY 0-200	260110LSRL	
0-300	260110LSRX	
0-400	260110LSSC	
0-500	260110LSSF	
0-600	260110LSSJ	
0-800	260110LSSN	
0-1000	260110LSSS	
0-1500	260110LSTC	
0-2000	260110LSTM	



AC MILLIAMMETERS — IRON VANE, PIVOT & JEWEL: SELF-CONTAINED, 50-400Hz*

0-10		26□240GZGZ	26□340GZGZ	26□440GZGZ
0-25		26□240HJHJ	26□340HJHJ	26□440HJHJ
0-50		26□240HYHY	26□340HYHY	26□440HYHY
0-100		26□240JRJR	26□340JRJR	26□440JRJR
0-250		26□240KDKD	26□340KDKD	26□440KDKD
0-500		26□240KMKM	26□340KMKM	26□440KMKM

NOTE ON ORDERING: The ranges and catalog numbers in this catalog refer to both surface and window mount panel meters. To specify your choice, replace the □ in the catalog number with either of the following: 0 for Surface Mount (Taut Band), 1 for Window Mount (Taut Band), 4 for Surface Mount (Pivot & Jewel) or 5 for Window Mount (Pivot & Jewel). (1½" is only available in Surface Mount (Taut Band). *Iron Vane, Pivot & Jewel use only 0 for Surface Mount, 1 for Window Mount.

AC Ammeters Cont'd

AC AMMETERS — IRON VANE, PIVOT & JEWEL: SELF-CONTAINED, 50-400Hz*

Rating & Scale \ Size	1½	2½	3½	4½
0-1		26□240LALA	26□340LALA	26□440LALA
0-1.5		26□240LCLC	26□340LCLC	26□440LCLC
0-2		26□240LELE	26□340LELE	26□440LELE
0-3		26□240LJLJ	26□340LJLJ	26□440LJLJ
0-5		26□240LSLS	26□340LSLS	26□440LSLS
0-10		26□240MTMT	26□340MTMT	26□440MTMT
0-15		26□240NDND	26□340NDND	26□440NDND
0-20		26□240NGNG	26□340NGNG	26□440NGNG
0-25		26□240NJNJ	26□340NJNJ	26□440NJNJ
0-30		26□240NLNL	26□340NLNL	26□440NLNL
0-50		26□240NTNT	26□340NTNT	26□440NTNT

AC AMMETERS — IRON VANE, PIVOT & JEWEL: TRANSFORMER RATED, 0-5 AMPERES, 50-400Hz*

0-10		26□240LSMT	26□340LSMT	26□440LSMT
0-15		26□240LSND	26□340LSND	26□440LSND
0-20		26□240LSNG	26□340LSNG	26□440LSNG
0-30		26□240LSNL	26□340LSNL	26□440LSNL
0-40		26□240LSNP	26□340LSNP	26□440LSNP
0-50		26□240LSNT	26□340LSNT	26□440LSNT
0-75		26□240LSPB	26□340LSPB	26□440LSPB
0-80		26□240LSPD	26□340LSPD	26□440LSPD
SCALE ONLY 0-100		26□240LSPK	26□340LSPK	26□440LSPK
0-150		26□240LSPZ	26□340LSPZ	26□440LSPZ
0-200		26□240LSRL	26□340LSRL	26□440LSRL
0-300		26□240LSRX	26□340LSRX	26□440LSRX
0-400		26□240LSSC	26□340LSSC	26□440LSSC
0-500		26□240LSSF	26□340LSSF	26□440LSSF
0-600		26□240LSSJ	26□340LSSJ	26□440LSSJ
0-800		26□240LSSN	26□340LSSN	26□440LSSN
0-1K		26□240LSVA	26□340LSVA	26□440LSVA
0-1.2K		26□240LSVB	26□340LSVB	26□440LSVB
0-1.5K		26□240LSVC	26□340LSVC	26□440LSVC
0-2.0K		26□240LSVE	26□340LSVE	26□440LSVE
0-3.0K		26□240LSVJ	26□340LSVJ	26□440LSVJ

*Iron Vane, Pivot & Jewel use only 0 for Surface Mount, 1 for Window Mount. Also see Page 29 For Transformer-Rated Meters

Frequency Meters (For 480V AC input contact factory)

FREQUENCY METERS — TAUT BAND OR PIVOT & JEWEL: SELF-CONTAINED

Voltage	Center Frequency	Scale Hertz	1½	2½	3½	4½
120	50	45-55		26□250AGAG	26□350AGAG	26□450AGAG
120	55	45-65		26□250AJAJ	26□350AJAJ	26□450AJAJ
120	60	55-65		26□250ANAN	26□350ANAN	26□450ANAN
120	400	380-420		26□250BKBK	26□350BKBK	26□450BKBK
208	50	45-55		26□250GGGG	26□350GGGG	26□450GGGG
208	55	45-65		26□250GJGJ	26□350GJGJ	26□450GJGJ
208	60	55-65		26□250GNGN	26□350GNGN	26□450GNGN
208	400	380-240		26□250HKHK	26□350HKHK	26□450HKHK
240	50	45-55		26□250DGDG	26□350DGDG	26□450DGDG
240	60	55-65		26□250DNDN	26□350DNDN	26□450DNDN
240	400	380-420		26□250EKEK	26□350EKEK	26□450EKEK
240	55	45-65		26□250DJDJ	26□350DJDJ	26□450DJDJ

NOTE ON ORDERING: The ranges and catalog numbers in this catalog refer to both surface and window mount panel meters. To specify your choice, replace the □ in the catalog number with either of the following: 0 for Surface Mount (Taut Band), 1 for Window Mount (Taut Band), 4 for Surface Mount (Pivot & Jewel) or 5 for Window Mount (Pivot & Jewel).

YOKOGAWA ◆ Terminal Resistance Values

ALL VALUES ARE ±15% TOLERANCE

New Big Look and Horizon Line

Rating and Scale	Taut Band	Pivot and Jewel

DC Voltmeters (See pages 2, 3, 8)

DC VOLTMETER — ZERO-LEFT

1.0 Volts	1,000 Ohms/Volt	1,000 Ohms/Volts
1.5 Volts		
3 Volts		
5 Volts		
8 Volts		
10 Volts		
15 Volts		
30 Volts		
80 Volts		
100 Volts		
150 Volts		
200 Volts		
250 Volts		
300 Volts		
500 Volts		
600 Volts		

DC VOLTMETERS — ZERO-LEFT, RATED 0-1 mA DC, FOR USE WITH EXTERNAL RESISTORS

SCALE ONLY 500 Volts	10.5 Ohms	42.4 Ohms
600 Volts	10.5 Ohms	42.4 Ohms
750 Volts	10.5 Ohms	42.4 Ohms

DC VOLTMETERS — ZERO-CENTER

5-0-5 Volts	1,000 Ohms/Volt	1,000 Ohms/Volt
10-0-10 Volts		
30-0-30 Volts		
50-0-50 Volts		
80-0-80 Volts		
150-0-150 Volts		
300-0-300 Volts		
500-0-500 Volts		
600-0-600 Volts		

DC VOLTMETERS — ZERO-CENTER, RATED 1-0-1 mA DC, FOR USE WITH EXTERNAL RESISTORS

SCALE ONLY 500-0-500 Volts	6.8 Ohms	22.4 Ohms
600-0-600 Volts	6.8 Ohms	22.4 Ohms
750-0-750 Volts	6.8 Ohms	22.4 Ohms

DC Ammeters (See pages 3-5, 8-10)

DC MICROAMMETERS — ZERO-LEFT

20 µA	2900 Ohms	
50 µA	2000 Ohms	
100 µA	484 Ohms	
200 µA	121 Ohms	880 Ohms
500 µA	40 Ohms	228 Ohms

DC MICROAMMETERS — ZERO-CENTER

20-0-20 µA	12000 Ohms	
50-0-50 µA	484 Ohms	
100-0-100 µA	121 Ohms	880 Ohms
200-0-200 µA	750 Ohms	228 Ohms
500-0-500 µA	10.5 Ohms	42.4 Ohms

New Big Look and Horizon Line

Rating and Scale	Taut Band	Pivot and Jewel

DC MILLIAMMETERS — ZERO-LEFT

1 mA	10.5 Ohms	42.4 Ohms
5 mA	20 Ohms	10.0 Ohms
10 mA	5.0 Ohms	5.0 Ohms
20 mA	2.39 Ohms	2.4 Ohms
25 mA	1.99 Ohms	2.0 Ohms
30 mA	1.66 Ohms	1.7 Ohms
50 mA	1.0 Ohms	1.0 Ohms
80 mA	0.64 Ohms	0.63 Ohms
100 mA	0.50 Ohms	0.50 Ohms
150 mA	0.33 Ohms	0.33 Ohms
200 mA	0.25 Ohms	0.25 Ohms
250 mA	0.2 Ohms	0.20 Ohms
300 mA	0.16 Ohms	0.167 Ohms
500 mA	0.10 Ohms	0.100 Ohms
800 mA	0.06 Ohms	0.063 Ohms

DC MILLIAMMETERS — ZERO-CENTER

1-0-1 mA	6.8 Ohms	22.4 Ohms
5-0-5 mA	5.0 Ohms	9.7 Ohms
10-0-10 mA	2.4 Ohms	4.9 Ohms
20-0-20 mA	1.2 Ohms	2.4 Ohms
25-0-25 mA	1.0 Ohms	2.0 Ohms
30-0-30 mA	0.88 Ohms	1.7 Ohms
50-0-50 mA	0.51 Ohms	1.0 Ohms
100-0-50 mA	0.51 Ohms	0.51 Ohms
150-0-150 mA	0.33 Ohms	0.33 Ohms
200-0-200 mA	0.25 Ohms	0.25 Ohms
250-0-250 mA	0.2 Ohms	0.20 Ohms
300-0-300 mA	0.17 Ohms	0.168 Ohms
500-0-500 mA	0.10 Ohms	0.100 Ohms

DC AMMETERS — ZERO-LEFT

1 Amp	0.050 Ohms	0.050 Ohms
1.5 Amp	0.033 Ohms	0.033 Ohms
2 Amp	0.025 Ohms	0.025 Ohms
3 Amp	0.0169 Ohms	0.0169 Ohms
5 Amp	0.010 Ohms	0.0100 Ohms
10 Amp	0.0050 Ohms	0.0050 Ohms
15 Amp	0.0033 Ohms	0.0033 Ohms
20 Amp	0.0025 Ohms	0.0025 Ohms
30 Amp	0.00167 Ohms	0.00167 Ohms
50 Amp	0.00100 Ohms	0.00100 Ohms

DC AMMETERS — ZERO-LEFT, 50 mV, SHUNT RATED

20 Amp		
30 Amp		
50 Amp		
75 Amp		
100 Amp	25 Ohms	12.5 Ohms
SCALE ONLY 150 Amp	Calibrated for use with two-way Shunt lead resistance of 0.065 Ohms	Calibrated for use with two-way Shunt lead resistance of 0.065 Ohms
200 Amp		
250 Amp		
300 Amp		
400 Amp		
500 Amp		
600 Amp		
800 Amp		
1 Kiloamp		
1.5 Kiloamp		
2 Kiloamp		

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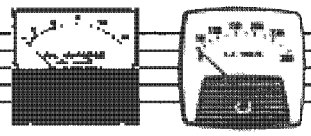


New Big Look and Horizon Line		
Rating and Scale	Taut Band	Pivot and Jewel

DC AMMETERS — ZERO-LEFT, 100 mV, SHUNT RATED

20 Amp	50 Ohms	25 Ohms
40 Amp		
50 Amp		
75 Amp		
100 Amp		
SCALE ONLY 150 Amp	Calibrated for use with two-way Shunt lead resistance of 0.065 Ohms	Calibrated for use with two-way Shunt lead resistance of 0.065 Ohms
200 Amp		
250 Amp		
300 Amp		
400 Amp		
500 Amp		
600 Amp		
800 Amp		
1 Kiloamp		
2 Kiloamp		

DC AMMETERS — ZERO-CENTER

1-0-1 Amp	0.0500 Ohms	0.0500 Ohms
2-0-2 Amp	0.0250 Ohms	0.0250 Ohms
5-0-5 Amp	0.0100 Ohms	0.0100 Ohms
10-0-10 Amp	0.0050 Ohms	0.0050 Ohms
15-0-15 Amp	0.0033 Ohms	0.0033 Ohms
20-0-20 Amp	0.0025 Ohms	0.0025 Ohms
30-0-30 Amp	0.00167 Ohms	0.00167 Ohms
50-0-50 Amp	0.00100 Ohms	0.00100 Ohms

DC AMMETERS — ZERO-CENTER, 50 mV, SHUNT RATED

SCALE ONLY 20-0-20 Amp	50 Ohms	25 Ohms
50-0-50 Amp		
75-0-75 Amp	Calibrated for use with two-way Shunt lead resistance of 0.065 Ohms	Calibrated for use with two-way Shunt lead resistance of 0.065 Ohms
100-0-100 Amp		
150-0-150 Amp		

AC Voltmeters (IRON VANE) See pages 5-6, 10-11

AC VOLTMETERS, SELF-CONTAINED, 60 Hz

3 Volts		11.1 Ohms
5 Volts		29.0 Ohms
10 Volts		110 Ohms
15 Volts		251 Ohms
30 Volts		779 Ohms
50 Volts		2,500 Ohms
100 Volts		10,000 Ohms
150 Volts		15,000 Ohms
300 Volts		70,250 Ohms
500 Volts		111,250 Ohms
600 Volts		140,000 Ohms

AC VOLTMETERS, SELF-CONTAINED, 400 Hz (IRON VANE)

150 Volts		15,268 Ohms
300 Volts		79,900 Ohms

AC VOLTMETERS, TRANSFORMER RATED, 60 Hz, 150 Volts (IRON VANE)

SCALE ONLY 600 Volts		15,000 Ohms
750 Volts		15,000 Ohms
3 Kv		15,000 Ohms

New Big Look and Horizon Line		
Rating and Scale	Taut Band	Pivot and Jewel

AC VOLTMETERS (RECTIFIER TYPE)

10 Volts		
15 Volts		
20 Volts		
25 Volts		
30 Volts		
50 Volts	1,000 Ohms/Volt	1,000 Ohms/Volt
80 Volts		
100 Volts		
150 Volts		
200 Volts		
250 Volts		
300 Volts		

AC Ammeters (See pages 6-7, 11-12)

AC MILLIAMMETERS, SELF-CONTAINED, 25-400 Hz (IRON VANE)

10 mA		2159 Ohms
25 mA		341 Ohms
50 mA		84 Ohms
100 mA		21 Ohms
200 mA		4.1 Ohms
500 mA		0.7 Ohms

AC AMMETERS — SELF-CONTAINED, 25-400 Hz (IRON VANE)

1 Amp		0.17 Ohms
3 Amp		0.015 Ohms
5 Amp		0.007 Ohms
8 Amp		0.003 Ohms
10 Amp		0.0024 Ohms
15 Amp		0.0016 Ohms
20 Amp		0.001 Ohms
30 Amp		0.0006 Ohms
50 Amp		0.0004 Ohms
80 Amp		0.0004 Ohms

AC AMMETERS — TRANSFORMER RATED 60 Hz (IRON VANE) 5 AMPERES

10 Amp		
15 Amp		
20 Amp		
30 Amp		
40 Amp		
50 Amp		
75 Amp		
SCALE ONLY 80 Amp		
100 Amp		
150 Amp		0.007 Ohms
200 Amp		
300 Amp		
400 Amp		
500 Amp		
600 Amp		
800 Amp		
1 Kiloamp		
1.2 Kiloamp		
1.5 Kiloamp		
2.0 Kiloamp		
3.0 Kiloamp		

YOKOGAWA ◆ Terminal Resistance Values

ALL VALUES ARE ±15% TOLERANCE

DC Voltmeters (See page 14)

DC MILLIVOLTMETERS — ZERO-LEFT

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
50 mV	10 Ohms	12.5 Ohms
100 mV	20 Ohms	25 Ohms

DC MILLIVOLTMETERS — ZERO-CENTER

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
50-0-50 mV	20 Ohms	25 Ohms
100-0-100 mV	40 Ohms	50 Ohms

DC VOLTMETERS — ZERO-LEFT

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
1 Volt thru 500 Volts	1000 Ohms/Volt	1000 Ohms/Volt
600 Volts	10000 Ohms/Volt	10000 Ohms/Volt

DC VOLTMETERS — ZERO-CENTER

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
5-0-5 Volts thru 500-0-500 Volts	1000 Ohms/Volt	
600-0-600 Volts	10000 Ohms/Volt	

DC Ammeters (See pages 15-16)

DC MICROAMMETERS — ZERO-LEFT

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
10 uA	5900 Ohms	N/A
20 uA	4600 Ohms	N/A
50 uA	2000 Ohms	6000 Ohms
100 uA	660 Ohms	1950 Ohms
200 uA	190 Ohms	980 Ohms
500 uA	116 Ohms	228 Ohms

DC MICROAMMETERS — ZERO-CENTER

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
10-0-10 uA	4600 Ohms	N/A
25-0-25 uA	2000 Ohms	6000 Ohms
50-0-50 uA	660 Ohms	1950 Ohms
100-0-100 uA	190 Ohms	980 Ohms
500-0-500 uA	32 Ohms	42.4 Ohms

DC MILLIAMMETERS — ZERO-LEFT

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
1 mA	32 Ohms	42.4 Ohms
2 mA	11.2 Ohms	22 Ohms
3 mA	30 Ohms	*
5 mA	3.5 Ohms	*
10 mA	4.9 Ohms	*
15 mA	3.3 Ohms	*
20 mA	2.5 Ohms	*
25 mA	1.9 Ohms	*
30 mA	1.7 Ohms	*
50 mA	1.0 Ohms	*
100 mA	0.49 Ohms	*
150 mA	0.33 Ohms	*
200 mA	0.25 Ohms	*
300 mA	0.17 Ohms	*
500 mA	0.10 Ohms	*
750 mA	0.067 Ohms	*

DC MILLIAMMETERS — ZERO-CENTER

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
1-0-1 mA	11.2 Ohms	22 Ohms
5-0-5 mA	9.9 Ohms	*
10-0-10 mA	5.0 Ohms	*
25-0-25 mA	2.0 Ohms	*
50-0-50 mA	1.0 Ohms	*
100-0-100 mA	0.53 Ohms	*
200-0-200 mA	0.25 Ohms	*
500-0-500 mA	0.10 Ohms	*

DC MILLIAMMETERS — SUPPRESSED ZERO

(Indicating receiving guage applications)

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
0.25-1.25 mA	32 Ohms	42.4 Ohms
1-5 mA	31 Ohms	*
4-20 mA	6.2 Ohms	*
10-50 mA	2.4 Ohms	*

DC AMMETERS — ZERO-LEFT, SELF-CONTAINED

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
1 Amp	0.05 Ohms	*
1.5 Amp	0.033 Ohms	*
2 Amp	0.025 Ohms	*
3 Amp	0.017 Ohms	*
5 Amp	0.010 Ohms	*
10 Amp	0.0050 Ohms	*
15 Amp	0.0033 Ohms	*
20 Amp	0.0025 Ohms	*
25 Amp	0.0020 Ohms	*
30 Amp	0.0017 Ohms	*
50 Amp	0.0010 Ohms	*

DC AMMETERS — ZERO-LEFT, 50mV, SHUNT RATED

SCALE ONLY

Rating and Scale	Stylist Series Taut Band	Stylist Series Pivot and Jewel
15 Amps thru 2000 Amps	10 Ohms	*

Rating and Scale	Stylist Series Pivot and Jewel
75 Amps thru 2000 Amps	20 Ohms

DC AMMETERS — ZERO-LEFT, 100mV, SHUNT RATED

SCALE ONLY

Rating and Scale	Stylist Series Pivot and Jewel
75 Amps thru 2000 Amps	20 Ohms

DC AMMETERS — ZERO-CENTER, SELF-CONTAINED

Rating and Scale	Stylist Series Pivot and Jewel
1-0-1 Amp	0.050 Ohms
3-0-3 Amp	0.017 Ohms
5-0-5 Amp	0.010 Ohms
10-0-10 Amp	0.0050 Ohms
15-0-15 Amp	0.0033 Ohms
25-0-25 Amp	0.0020 Ohms
50-0-50 Amp	0.0010 Ohms

DC AMMETERS — ZERO-CENTER, 50mV, SHUNT RATED

SCALE ONLY

Rating and Scale	Stylist Series Pivot and Jewel
15-0-15 Amps thru 500-0-500 Amps	20 Ohms

*Contact factory

IP7014988

Stylist Series	
Rating and Scale	Taut Band

AC Voltmeters (See page 17)

AC VOLTMETERS — SELF-CONTAINED, RECTIFIER TYPE

3 Volts thru 600 Volts	900 Ohms/Volt

AC VOLTMETERS — TRANSFORMER RATED, 0-150V, RECTIFIER TYPE

750 Volts thrugh 3000 Volts (SCALE ONLY)	130 KOhms

AC VOLTMETERS — EXPANDED SCALE, RECTIFIER TYPE

105-125 Volts thru 190-270 Volts	225 Ohms/Volt

Stylist Series	
Rating and Scale	Pivot & Jewel

AC VOLTMETERS — IRON VANE, SELF-CONTAINED, 60 Hz

3 Volts	11.1 Ohms
5 Volts	29.0 Ohms
10 Volts	110.0 Ohms
15 Volts	251.0 Ohms
30 Volts	778.0 Ohms
50 Volts	2.5 KOhms
100 Volts	10.1 KOhms
150 Volts	15.1 KOhms
300 Volts	70.3 KOhms
500 Volts	117.3 KOhms
600 Volts	139.9 KOhms

AC VOLTMETERS — IRON VANE, TRANSFORMER RATED, 150 VOLTS, 60Hz

600 Volts thrugh 3KVolts (SCALE ONLY)	16.1 KOhms

Stylist Series		
Rating and Scale	Taut Band	Pivot and Jewel

AC Ammeters (See pages 17-19)

AC MILLIAMMETERS — SELF-CONTAINED, RECTIFIER TYPE

1 mA	630 Ohms	*
5 mA	130 Ohms	*
10 mA	95 Ohms	*
25 mA	38 Ohms	*
50 mA	25 Ohms	*
100 mA	15 Ohms	*
200 mA	9 Ohms	*
500 mA	.26 Ohms	*

Stylist Series		
Rating and Scale	Taut Band	Pivot and Jewel

AC AMMETERS — SELF-CONTAINED, RECTIFIER TYPE

1 Amp	.09 Ohms	*
1.5 Amp	.07 Ohms	*
2 Amp	.05 Ohms	*
3 Amp	.03 Ohms	*
5 Amp	0.2 Ohms	*
10 Amp	0.1 Ohms	*
15 Amp	.007 Ohms	*
20 Amp	.005 Ohms	*
25 Amp	.005 Ohms	*
30 Amp	.003 Ohms	*
50 Amp	.002 Ohms	*

AC AMMETERS — TRANSFORMER RATED, 0-5A, RECTIFIER TYPE

60 Amps thru 2000 Amps (SCALE ONLY)	.02 Ohms	*

AC AMMETERS — SEPARATE TRANSFORMER RECTIFIER TYPE (1½" SIZE)

50 Amps thru 2000 Amps	.015 Ohms	*

Stylist Series	
Rating and Scale	Pivot & Jewel

AC MILLIAMMETERS — IRON VANE, SELF-CONTAINED, 50-400Hz

10 mA	2.158 KOhms
25 mA	341.0 Ohms
50 mA	83.7 Ohms
100 mA	21.0 Ohms
250 mA	2.75 Ohms
500 mA	.704 Ohms

AC AMMETERS — IRON VANE, SELF-CONTAINED, 50-400 Hz

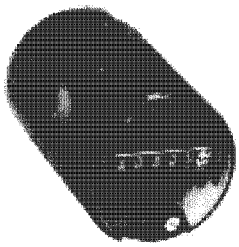
1 Amp	.17 Ohms
1.5 Amps	.110 Ohms
2 Amps	.044 Ohms
3 Amps	.0153 Ohms
5 Amps	.0071 Ohms
10 Amps	.0024 Ohms
15 Amps	.0017 Ohms
20 Amps	.0009 Ohms
25 Amps	.0007 Ohms
30 Amps	.0005 Ohms
50 Amps	.0004 Ohms

AC AMMETERS — IRON VANE, TRANSFORMER RATED, 0-5 AMPS, 50-400Hz

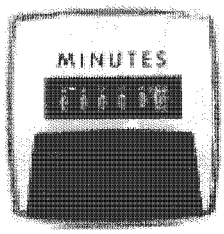
10 Amps thru 3KAmps (Scale Only)	.0071 Ohms

*Contact Factory

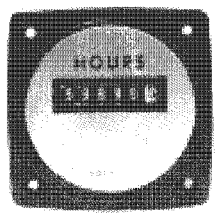
YOKOGAWA ◆ Elapsed Time Meters



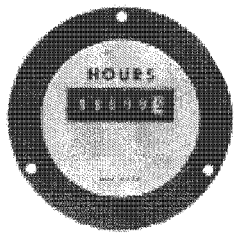
Back of Panel Unmounted



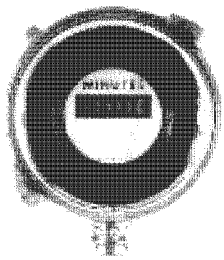
New Big Look Panel Mounted



Square Case



Round Case



Conduit Case

Specifications

Accuracy: Matches frequency control of power system.

Vibration Shock: Meets ANSI Specification C39.1

Materials: Case of clear Polycarbonate, frame of black Polycarbonate, brass terminal studs, Polycarbonate front covers.

Safety: Type 240 elapsed-time meters are recognized under the Component Program of Underwriters' Laboratories. (UL File #E44857) & CSA

Input Range: All Type 240 models available to operate on 120 or 208/240 or 480 volts AC, 50 or 60 Hertz.

Sealing: All non-reset Type 240 models are weather resistant. Sealed window and no-through screw holes for flange or back-of-panel mounting protect motor, counter, and gearing from rain or panel wash-down.

Presentation: 6-digit counter in 9/32" high hours and tenths of hours or minutes and tenths of minutes.

Insulation Level: Operating at 120, 208, 240 or 480 volts AC, will pass Hi-pot of 2000 VRMS for one minute.

Burden: 3 Watts typical.

Dimensions: See pages 38 & 39.

Motor: Telechron, Model S-1.

Features:
- Back-of-panel model
- 2½" and 3½" New Big Look models
- 2½" and 3½" Round and Square models
- Conduit-case models
- Complete interchangeability physically and electrically with most GE Types 235 and 236 models
- Optional 3 stud mounting is available on 3½" New Big Look style 240 meters only.

Motor Volt AC	Nonreset Type		Reset Type	
	Register in Minutes	Register in Hours	Register in Minutes	Register in Hours
2½-INCH NEW BIG LOOK — 60Hz				
120	240 213 AAAB	240 211 AAAB	240 214 AAAB	240 212 AAAB
208/240	240 213 ABAB	240 211 ABAB	240 214 ABAB	240 212 ABAB
480	240 213 ACAB	240 211 ACAB	240 214 ACAB	240 212 ACAB
3½-INCH NEW BIG LOOK — 60 Hz				
120	240 313 AAAB	240 311 AAAB	240 314 AAAB	240 312 AAAB
208/240	240 313 ABAB	240 311 ABAB	240 314 ABAB	240 312 ABAB
480	240 313 ACAB	241 311 ACAB	240 314 ACAB	240 312 ACAB
SQUARE CASE 2½-INCH — 60 Hz				
120	240 613 AAAD	240 611 AAAD	240 614 AAAD	240 612 AAAD
208/240	240 613 ABAD	240 611 ABAC	240 614 ABAD	240 612 ABAD
480	240 613 ACAD	240 611 ACAD	240 614 ACAD	240 612 ACAD
SQUARE CASE 3½-INCH — 60 Hz				
120	240 713 AAAD	240 711 AAAD	240 714 AAAD	240 712 AAAD
208/240	240 713 ABAD	240 711 ABAD	240 714 ABAD	240 712 ABAD
480	240 713 ACAD	240 711 ACAD	240 714 ACAD	240 712 ACAD
ROUND CASE 2½-INCH — 60 Hz				
120	240 633 AAAE	240 631 AAAE	240 634 AAAE	240 632 AAAE
208/40	240 633 ABAE	240 631 ABAE	240 634 ABAE	240 632 ABAE
480	240 633 ACAE	240 631 ACAE	240 634 ACAE	240 632 ACAE
ROUND CASE 3½-INCH — 60 Hz				
120	240 733 AAAE	240 731 AAAE	240 734 AAAE	240 732 AAAE
208/40	240 733 ABAE	240 731 ABAE	240 734 ABAE	240 732 ABAE
480	240 733 ACAE	240 731 ACAE	240 734 ACAE	240 732 ACAE

BACK-OF-PANEL — 60 Hz

120 208/240 480	240 003 AAAA 240 003 ABAA 240 003 ACAA	240 001 AAAA 240 001 ABAA 240 001 ACAA	240 004 AAAA 240 004 ABAA 240 004 ACAA	240 002 AAAA 240 002 ABAA 240 002 ACAA

CONDUIT-MOUNTED CASE 2½-INCH — 60 Hz†

120 208/240 480	240 253 AAAF 240 253 ABAF 240 253 ACAF	240 251 AAAF 240 251 ABAF 240 251 ACAF		

† Replacement meters for conduit-mounted case models not available as a separate item. However, motors can be supplied as a renewal part.

50-HERTZ RATINGS FOR NEW BIG LOOK
For 50 Hz service simply select the identical 60 Hz catalog number and change letters 7 & 8 as follows:

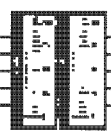
240213 * * AB
- AA = 120V, 60 Hz
- AB = 208/240V, 60 Hz
- AC = 480V, 60 Hz
- AD = 120V, 50 Hz
- AE = 208/240V, 50 Hz
- AF = 480V, 50 Hz

OPTIONAL 3-STUD MOUNTING
For 3-stud mounting option (3½" New Big Look only) simply select the identical 4-stud catalog number and change letters 9 & 10 as follows:

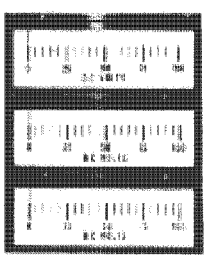
240313AA**
- AB = Std 4 stud mounting
- AC = Optional 3 stud mounting

Conduit case #2579K10G0700 can be ordered as a replacement item for the 240 25***** elapsed time meter assembly or for use with a 2½" Big Look meter.

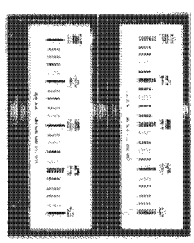
Edgewise Panel Meters



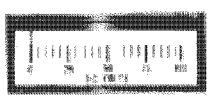
Type 185 Edgewise Panel Meters



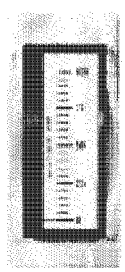
Type 185
3 Stack Mounted



Type 185
2 Stack Mounted



Horizontal Type 185



Type 185
Vertical
Meter with Bezel

Features: Completely shielded case. No special calibration required for panel material — Dust-tight cases — Stack mounting of meters is possible with all sides of meter case flush — Optional bezel and mounting bracket for 1- or 3-unit stack — Zero regulator provided in rear of case.

NOTE: Mounting hardware is not included.

Accuracy: DC Meters ±2% of full scale. AC rectifier type ±3% (60 Hertz sine wave at 25°C).

Overload: Voltmeter — 50% momentary. 20% sustained. Ammeter — 900% momentary. 20% sustained.

Scale Data: 53 degrees rotation. Length — 1.785".

Insulation Level: 1800 VRMS Hi-pot.

Response Time:
3 secons (max.) for microammeters;
2 seconds (max.) for all other DC ratings; and
2.5 seconds (max.) for AC ratings.

Overshoot: Maximum of 40%.

Dimensions: See page 37.

Bezel and Mounting Assembly	Type of Mounting	Cat. No.
Assembly includes — Bezel mounting bracket(s), bolts, nuts, washers, speed nuts	For mounting one meter only For stack mounting three meters	4149K18G0778 4149K18G0780

DC Ratings

Rating and Scale	Terminal Resistance Ohms ±15%	Horizontal Scale	Vertical Scale

DC VOLTMETERS — ZERO-LEFT, ZERO-BOTTOM, SELF-CONTAINED, LINEAR-SCALE 1000 OHMS/VOLT

10 V	1000 Ohms/Volt	185 011 MTMT	185 013 MTMT
15 V		185 011 NDND	185 013 NDND
30 V		185 011 NLNL	185 013 NLNL
50 V		185 011 NTNT	185 013 NTNT
100 V		185 011 PKPK	185 013 PKPK
150 V		185 011 PZPZ	185 013 PZPZ
300 V		185 011 RXRX	185 013 RXRX

DC VOLTMETERS — ZERO-CENTER, SELF-CONTAINED, 2000 OHMS/VOLT

15-0-15 V	2000 Ohms/Volt	185 012 NDND	185 014 NDND
50-0-50 V	2000 Ohms/Volt	185 012 NTNT	185 014 NTNT
150-0-150 V	2000 Ohms/Volt	185 012 PZPZ	185 014 PZPZ

DC VOLTMETERS — ZERO-LEFT, ZERO-BOTTOM, RATED 0-1 mA, FOR USE WITH EXTERNAL RESISTORS, RESISTORS NOT INCLUDED (SEE PAGE 29 FOR RESISTORS)

500 V	34.4 Ohms	185 171 FASF	185 173 FASF
600 V	34.4 Ohms	185 171 FASJ	185 173 FASJ
750 V	34.4 Ohms	185 171 FASM	185 173 FASM

DC MICROAMMETERS — ZERO-LEFT, ZERO-BOTTOM, SELF-CONTAINED, LINEAR-SCALE

50 µA	2200 Ohms	185 111 CYCY	185 113 CYCY
100 µA	1100 Ohms	185 111 DRDR	185 113 DRDR
500 µA	148 Ohms	185 111 EMEM	185 113 EMEM

DC MICROAMMETERS — ZERO-CENTER, SELF-CONTAINED

50-0-50 µA	1100 Ohms	185 112 CYCY	185 114 CYCY
500-0-500 µA	34.4 Ohms	185 112 EMEM	185 114 EMEM

DC MILLIAMMETERS — ZERO-LEFT, ZERO-BOTTOM, SELF-CONTAINED, LINEAR-SCALE

1 mA	34.4 Ohms	185 111 FAFA	185 113 FAFA
5 mA	10.2 Ohms	185 111 FXFX	185 113 FXFX
10 mA	5.0 Ohms	185 111 GZGZ	185 113 GZGZ
20 mA	2.5 Ohms	185 111 HFHF	185 113 HFHF
50 mA	1.0 Ohms	185 111 HYHY	185 113 HYHY
100 mA	0.5 Ohms	185 111 JRJR	185 113 JRJR
300 mA	0.167 Ohms	185 111 KGKG	185 113 KGKG
500 mA	0.100 Ohms	185 111 KMKM	185 113 KMKM

DC MILLIAMMETERS — ZERO-CENTER, SELF-CONTAINED

1-0-1 mA	50.5 Ohms	185 112 FAFA	185 114 FAFA
5-0-5 mA	5.0 Ohms	185 112 FXFX	185 114 FXFX
10-0-10 mA	2.5 Ohms	185 112 GZGZ	185 114 GZGZ
50-0-50 mA	0.5 Ohms	185 112 HYHY	185 114 HYHY
500-0-500 mA	0.05 Ohms	185 112 KMKM	185 114 KMKM

DC AMMETERS — ZERO-LEFT, ZERO-BOTTOM, SELF-CONTAINED, LINEAR-SCALE

1 Amp	.050 Ohms	185 111 LALA	185 113 LALA
5 Amp	.010 Ohms	185 111 LSLS	185 113 LSLS
10 Amp	.005 Ohms	185 111 MTMT	185 113 MTMT

DC AMMETERS — ZERO-CENTER, SELF-CONTAINED

5-0-5 Amp	.005 Ohms	185 112 LSLS	185 114 LSLS

DC AMMETERS — ZERO-LEFT, ZERO-BOTTOM, LINEAR-SCALE 50 mV SHUNT RATED, SHUNTS & LEADS NOT INCLUDED. (LEAD RES. RANGE: .05-.07Ω)

20 Amp	12.7 Ohms	185 121 ECNG	185 123 ECNG
50 Amp	12.7 Ohms	185 121 ECNT	185 123 ECNT
300 Amp	12.7 Ohms	185 121 ECRX	185 123 ECRX
500 Amp	12.7 Ohms	185 121 ECSF	185 123 ECSF

AC Ratings

Rating and Scale	Terminal Resistance Ohms ±15%	Horizontal Scale	Vertical Scale

AC VOLTMETERS — RECTIFIER TYPE, ACCURACY ±3 PERCENT, SELF-CONTAINED, LINEAR-SCALE 1000 OHMS/VOLT

10 V	1000 Ohms/Volt	185 051 MTMT	185 053 MTMT
15 V		185 051 NDND	185 053 NDND
30 V		185 051 NLNL	185 053 NLNL
50 V		185 051 NTNT	185 053 NTNT
100 V		185 051 PKPK	185 053 PKPK
150 V		185 051 PZPZ	185 053 PZPZ

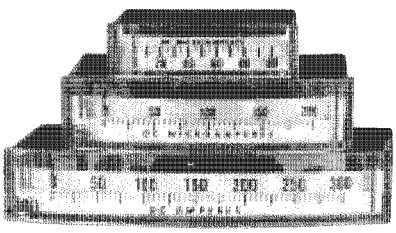
AC MICROAMMETERS — RECTIFIER TYPE, ACCURACY ±3 PERCENT, SELF-CONTAINED, LINEAR-SCALE

500 µA	1000 Ohms	185 151 EMEM	185 153 EMEM

AC MILLIAMMETERS — RECTIFIER TYPE, ACCURACY ±3 PERCENT, SELF-CONTAINED, LINEAR-SCALE

3 mA	570 Ohms	185 151 FAFA	185 153 FAFA
5 mA	147 Ohms	185 151 FXFX	185 153 FXFX
10 mA	86 Ohms	185 151 GZGZ	185 153 GZGZ
20 mA	57 Ohms	185 151 HFHF	185 153 HFHF

Series 280 Thin Edgewise Panel Meters



Specifications

These meters are designed to meet all applicable sections of ANSI C39.1.

Accuracy: ±2% of full scale, DC meters; ±3% with 60 Hz sine wave at 25°C for AC rectifier type meters.

Overload: DC Voltmeters — 20% momentary and sustained; DC ammeters (momentary) — 10 times the rated current for 10 consecutive intervals of .5 second with 1 minute intervals between successive applications; DC ammeters (sustained) — 20% for 6 hours.

Dielectric (Hi-pot): 1500 VRMS for 1½" and 2½" sizes: 2600 VRMS for 3½" size.

Response Time: 3 seconds max for µA meters, 2 seconds (max.) for mA, A, mV, & V meters.

Pointer Color: red standard.

Bezel and Mounting Hardware: Included with meter. See below for additional information.

Overshoot: 25% (max.) for 1½" size, 40% (max.) for 2½" and 3½" sizes.

Scale Data: All three sizes designed for 53 degrees deflection. Scale lengths are 1½" size = 1.25", 2½" size = 1.93", 3½" size = 2.70". Note: All scales have linear distributions. 10V, 15V, 30V Rectifier scales will be non-linear.

Dimensions: See page 38.

Mounting Hardware

Item	Cat. No.
Bezel and Hardware Kit 1½"	4149K18G0001
Bezel and Hardware Kit 2½"	4149K18G0003
Bezel and Hardware Kit 3½"	4149K18G0004
Bezel for 21/2" Meters Stacked	4149K18G0002

Series 280 DC Voltmeters (Taut Band)

Size		1½		2½		3½	
Rating and Scale	Terminal Resistance Ohms ±15%	Horizontal Scale	Vertical Scale	Horizontal Scale	Vertical Scale	Horizontal Scale	Vertical Scale
DC VOLTMETERS							
0-10 Volts	1000 Ohms/Volt	286 011 MTMT	286 013 MTMT	287 011 MTMT	287 013 MTMT	288 011 MTMT	288 013 MTMT
0-15 Volts		286 011 NDND	286 013 NDND	287 011 NDND	287 013 NDND	288 011 NDND	288 013 NDND
0-30 Volts		286 011 NLNL	286 013 NLNL	287 011 NLNL	287 013 NLNL	288 011 NLNL	288 013 NLNL
0-50 Volts		286 011 NTNT	286 013 NTNT	287 011 NTNT	287 013 NTNT	288 011 NTNT	288 013 NTNT
0-100 Volts		286 011 PKPK	286 013 PKPK	287 011 PKPK	287 013 PKPK	288 011 PKPK	288 013 PKPK
0-150 Volts		286 011 PZPZ	286 013 PZPZ	287 011 PZPZ	287 013 PZPZ	288 011 PZPZ	288 013 PZPZ
0-200 Volts		.....	.....	287 011 RLRL	287 013 RLRL	288 011 RLRL	288 013 RLRL
0-300 Volts		.....	.....	287 011 RXRX	287 013 RXRX	288 011 RXRX	288 013 RXRX
15-0-15 Volts		286 012 NDND	286 014 NDND	287 012 NDND	287 014 NDND	288 012 NDND	288 014 NDND
30-0-30 Volts		286 012 NLNL	286 014 NLNL	287 012 NLNL	287 014 NLNL	288 012 NLNL	288 014 NLNL
150-0-150 Volts		.....	.....	287 012 PZPZ	287 014 PZPZ	288 012 PZPZ	288 014 PZPZ

DC VOLTMETERS — 0-1 mA, FOR USE WITH EXTERNAL RESISTORS, RESISTORS NOT INCLUDED (SEE PAGE 29 FOR RESISTORS)

SCALE ONLY

0-500 Volts	43.2 Ohms	286 171 FASF	286 173 FASF	287 171 FASF	287 173 FASF	288 171 FASF	288 173 FASF
0-600 Volts	43.2 Ohms	286 171 FASJ	286 173 FASJ	287 171 FASJ	287 173 FASJ	288 171 FASJ	288 173 FASJ
0-750 Volts	43.2 Ohms	286 171 FASM	286 173 FASM	287 171 FASM	287 173 FASM	288 171 FASM	288 173 FASM

Series 280 DC Ammeters (Taut Band)

Size		1½		2½		3½	
Rating and Scale	Terminal Resistance Ohms ±15%	Horizontal Scale	Vertical Scale	Horizontal Scale	Vertical Scale	Horizontal Scale	Vertical Scale
DC AMMETERS — SELF-CONTAINED							
0-50 µA	1,980 Ohms	286 111 CYCY	286 113 CYCY	287 111 CYCY	287 113 CYCY	288 111 CYCY	288 113 CYCY
0-100 µA	990 Ohms	286 111 DRDR	286 113 DRDR	287 111 DRDR	287 113 DRDR	288 111 DRDR	288 113 DRDR
0-200 µA	1,340 Ohms	286 111 EAEA	286 113 EAEA	287 111 EAEA	287 113 EAEA	288 111 EAEA	288 113 EAEA
0-500 µA	235 Ohms	286 111 EMEM	286 113 EMEM	287 111 EMEM	287 113 EMEM	288 111 EMEM	288 113 EMEM
0-1 mA	43.2 Ohms	286 111 FAFA	286 113 FAFA	287 111 FAFA	287 113 FAFA	288 111 FAFA	288 113 FAFA
0-5 mA	3.3 Ohms	286 111 FXFX	286 113 FXFX	287 111 FXFX	287 113 FXFX	288 111 FXFX	288 113 FXFX
0-10 mA	5 Ohms	286 111 GZGZ	286 113 GZGZ	287 111 GZGZ	287 113 GZGZ	288 111 GZGZ	288 113 GZGZ
0-25 mA	2.0 Ohms	286 111 HJHJ	286 113 HJHJ	287 111 HJHJ	287 113 HJHJ	288 111 HJHJ	288 113 HJHJ
0-50 mA	1.0 Ohms	286 111 HYHY	286 113 HYHY	287 111 HYHY	287 113 HYHY	288 111 HYHY	288 113 HYHY
0-100 mA	0.5 Ohms	286 111 JRJR	286 113 JRJR	287 111 JRJR	287 113 JRJR	288 111 JRJR	288 113 JRJR
0-250 mA	0.2 Ohms	286 111 KDKD	286 113 KDKD	287 111 KDKD	287 113 KDKD	288 111 KDKD	288 113 KDKD
0-500 mA	0.1 Ohms	286 111 KMKM	286 113 KMKM	287 111 KMKM	287 113 KMKM	288 111 KMKM	288 113 KMKM
0-1 Amp	0.05 Ohms	286 111 LALA	286 113 LALA	287 111 LALA	287 113 LALA	288 111 LALA	288 113 LALA
0-1.5 Amp	0.033 Ohms	286 111 LCLC	286 113 LCLC	287 111 LCLC	287 113 LCLC	288 111 LCLC	288 113 LCLC
0-2 Amp	0.025 Ohms	286 111 LELE	286 113 LELE	287 111 LELE	287 113 LELE	288 111 LELE	288 113 LELE
0-3 Amp	0.0167 Ohms	286 111 LJLJ	286 113 LJLJ	287 111 LJLJ	287 113 LJLJ	288 111 LJLJ	288 113 LJLJ
0-5 Amp	0.01 Ohms	286 111 LSLS	286 113 LSLS	287 111 LSLS	287 113 LSLS	288 111 LSLS	288 113 LSLS
50-0-50 µA	990 Ohms	286 112 CYCY	286 114 CYCY	287 112 CYCY	287 114 CYCY	288 112 CYCY	288 114 CYCY
100-0-100 µA	1,340 Ohms	286 112 DRDR	286 114 DRDR	287 112 DRDR	287 114 DRDR	288 112 DRDR	288 114 DRDR
500-0-500 µA	43.2 Ohms	286 112 EMEM	286 114 EMEM	287 112 EMEM	287 114 EMEM	288 112 EMEM	288 114 EMEM
01-0-1 mA	22.2 Ohms	286 112 FAFA	286 114 FAFA	287 112 FAFA	287 114 FAFA	288 112 FAFA	288 114 FAFA
5-0-5 mA	5 Ohms	286 112 FXFX	286 114 FXFX	287 112 FXFX	287 114 FXFX	288 112 FXFX	288 114 FXFX
50-0-50 mA	0.5 Ohms	.....	.....	287 112 HYHY	287 114 HYHY	288 112 HYHY	288 114 HYHY
5-0-5 Amp	0.005 Ohms	286 112 LSLS	286 114 LSLS	287 112 LSLS	287 114 LSLS	288 112 LSLS	288 114 LSLS
DC AMMETERS — SHUNT RATED (LEAD RES. RANGE: .05-.07Ω)*							
1 Amp	(0-50 mV) 10 Ohms	286 121 ECLA	286 123 ECLA	287 121 ECLA	287 123 ECLA	288 121 ECLA	288 123 ECLA
5 Amp	(0-50 mV) 10 Ohms	286 121 ECLS	286 123 ECLS	287 121 ECLS	287 123 ECLS	288 121 ECLS	288 123 ECLS
10 Amp	(0-50 mV) 10 Ohms	286 121 ECMT	286 123 ECMT	287 121 ECMT	287 123 ECMT	288 121 ECMT	288 123 ECMT
20 Amp	(0-50 mV) 10 Ohms	286 121 ECNG	286 123 ECNG	287 121 ECNG	287 123 ECNG	288 121 ECNG	288 123 ECNG
50 Amp	(0-50 mV) 10 Ohms	286 121 ECNT	286 123 ECNT	287 121 ECNT	287 123 ECNT	288 121 ECNT	288 123 ECNT
300 Amp	(0-50 mV) 10 Ohms	286 121 ECRX	286 123 ECRX	287 121 ECRX	287 123 ECRX	288 121 ECRX	288 123 ECRX
500 Amp	(0-50 mV) 10 Ohms	286 121 ECSF	286 123 ECSF	287 121 ECSF	287 123 ECSF	288 121 ECSF	288 123 ECSF
1 Amp	(0-100 mV) 20 Ohms	286 121 GBLA	286 123 GBLA	287 121 GBLA	287 123 GBLA	288 121 GBLA	288 123 GBLA
5 Amp	(0-100 mV) 20 Ohms	286 121 GBLS	286 123 GBLS	287 121 GBLS	287 123 GBLS	288 121 GBLS	288 123 GBLS
10 Amp	(0-100 mV) 20 Ohms	286 121 GBMT	286 123 GBMT	287 121 GBMT	287 123 GBMT	288 121 GBMT	288 123 GBMT
20 Amp	(0-100 mV) 20 Ohms	286 121 GMNG	286 123 GMNG	287 121 GMNG	287 123 GMNG	288 121 GMNG	288 123 GMNG
50 Amp	(0-100 mV) 20 Ohms	286 121 GBNT	286 123 GBNT	287 121 GBNT	287 123 GBNT	288 121 GBNT	288 123 GBNT
300 Amp	(0-100 mV) 20 Ohms	286 121 GBRX	286 123 GBRX	287 121 GBRX	287 123 GBRX	288 121 GBRX	288 123 GBRX
500 Amp	(0-100 mV) 20 Ohms	286 121 GBSF	286 123 GBSF	287 121 GBSF	287 123 GBSF	288 121 GBSF	288 123 GBSF

SCALE ONLY

*Shunts not included. See Page 29 for 50mV shunts.

Series 280 AC Voltmeters

AC VOLTMETERS — RECTIFIER TYPE

0-10 Volts	1000 Ohms/volt	286 051 MTMT	286 053 MTMT	287 051 MTMT	287 053 MTMT	288 051 MTMT	288 053 MTMT
0-15 Volts		286 051 NDND	286 053 NDND	287 051 NDND	287 053 NDND	288 051 NDND	288 053 NDND
0-30 Volts		286 051 NLNL	286 053 NLNL	287 051 NLNL	287 053 NLNL	288 051 NLNL	288 053 NLNL
0-50 Volts		286 051 NTNT	286 053 NTNT	287 051 NTNT	287 053 NTNT	288 051 NTNT	288 053 NTNT
0-100 Volts		286 051 PKPK	286 053 PKPK	287 051 PKPK	287 053 PKPK	288 051 PKPK	288 053 PKPK
0-150 Volts		286 051 PZPZ	286 053 PZPZ	287 051 PZPZ	287 053 PZPZ	288 051 PZPZ	288 053 PZPZ

Series 280 AC Ammeters

AC AMMETERS — RECTIFIER TYPE Δ

0-500 µA	1267 Ohms	286 151 EMEM	286 153 EMEM	287 151 EMEM	287153 EMEM	288 151 EMEM	288 153 EMEM
0-1 mA	758 Ohms	286 151 FAFA	286 153 FAFA	287 151 FAFA	287153 FAFA	288 151 FAFA	288 153 FAFA
0-5 mA	196 Ohms	286 151 FXFX	286 153 FXFX	287 151 FXFX	287153 FXFX	288 151 FXFX	288 153 FXFX
0-10 mA	97 Ohms	286 151 GZGZ	286 153 GZGZ	287 151 GZGZ	287153 GZGZ	288 151 GZGZ	288 153 GZGZ
0-20 mA	55 Ohms	286 151 HFHF	286 153 HFHF	287 151 HFHF	287153 HFHF	288 151 HFHF	288 153 HFHF

Δ A 5 AMP AC self-contained 3½" (Type 288) is available as a special, but is not per ANSI C39.1. Contact factory for more information.

IP7014994

Parts and Accessories

AC CURRENT TRANSFORMERS

Current Ratio In Amperes Primary: Secondary	** Catalog number	Accuracy at 60 Hz	Burden VA @ 60Hz	Window diameter
50:5	5RL-500	±2%	1.0	1.56"
75:5	5RL-750	±2%	1.5	1.56"
100:5	5RL-101	±2%	2.0	1.56"
150:5	5RL-151	±1%	5.0	1.56"
200:5	5RL-201	±1%	5.0	1.56"
250:5	5RL-251	±1%	10.0	1.56"
300:5	5RL-301	±1%	12.5	1.56"
400:5	5RL-401	±1%	12.5	1.56"
500:6	5RL-501	±1%	20.0	1.56"
600:5	5RL-601	±1%	25.0	1.56"
750:5	5RL-751	±1%	25.0	1.56"
800:5	5RL-801	±1%	25.0	1.56"
1000:5	5RL-102	±1%	25.0	1.56"
1200:5	5RL-122	±1%	30.0	1.56"

** This is a toroidal type donut transformer with a 24" flying leads. For other styles, ratios and window diameters see transformer catalog 500CTPT-B.

AC VOLTAGE TRANSFORMERS

Voltage Rating primary:secondary	Turns Ratio	1 Phase Catalog No.	Open Delta Catalog No. *	3 Phase Catalog No. **
69.3:120	0.58:1	467-069	469-069	3VT-460-069F
120:120	1:1	467-120	469-120	3VT-460-120F
208:120	1.73:1	467-208	469-208	N/A
240:120	2:1	467-240	469-240	3VT-460-240F
288:120	2.4:1	467-288	469-288	3VT-460-288F
300:120	2.5:1	467-300	469-300	3VT-460-300F
480:120	4:1	467-480	469-480	3VT-460-480F
600:120	5:1	467-600	469-600	3VT-460-600F

*2 transformers in one case. ** 480V & 600V connected line to line. For other ratings. See 500CTPT-B.

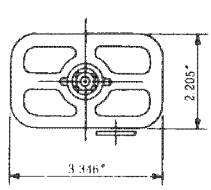
RESISTORS

1000 Ohms/Volt, 1 milliampere DC full scale

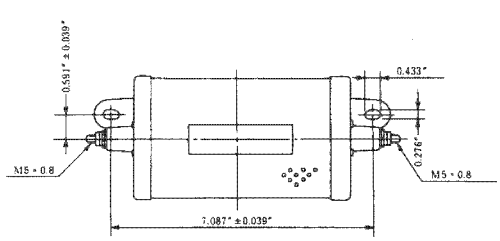
*Voltage level	Catalog No.
500 V	2227 01
600 V	2227 02
750 V	2227 03
800 V	2227 04
1 kV	2227 05
1.5 kV	2227 06
2 kV	2227 07

*Other voltage levels available.

Dimensions



SIDE VIEW



TOP VIEW

WINDOW ASSEMBLIES

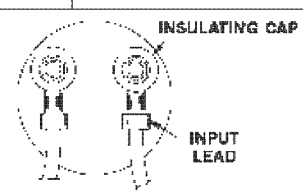
Size	Big Look	Horizon Line	Stylist Surface mt.	Stylist Window mt.
1 1/2"	9007K17G7700	9007K17G0707	B9015JA	N/A
2 1/2"	9007K17G7701	9007K17G0704	B9016NG	B9016NL
3 1/2"	9007K17G7702	9007K17G0705	B9016PG	B9016PL
4 1/2"	9007K17G7703	9007K17G0706	B9016QG	B9016QL

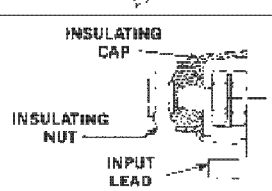
GASKETS, MASKS, BEZEL KITS

Size	Big Look Gasket	Horizon Line Mask	Stylist Surface mount only: Metallic Bezel Kit	Stylist Surface mount only: Black Bezel Kit
1 1/2"	N/A	5203K21P0001	N/A	N/A
2 1/2"	3830K20P7005	5203K18P0001	B9015KX	B9015KY
3 1/2"	3830K20P7003	5203K19P0001	B9015LX	B9015LY
4 1/2"	3830K20P7004	5203K20P0001	B9015MX	B9015MY

INSULATING CAPNUTS

For Stylist meters 10-32 terminals	See below	B9015HM
For BL/HL Meters 1/4-28 terminals	See below	B9015HN





DC AMMETER SHUNTS - 50 millivolt only

Catalog no.	Rating	Catalog no.	Rating
221501	1 Amp	221514	150 Amp
221502	1.5 Amp	221515	200 Amp
221503	2 Amp	221516	300 Amp
221504	3 Amp	221601	500 Amp
221505	5 Amp	221602	750 Amp
221506	7.5 Amp	221603	1 Kiloamp
221507	10 Amp	221701	1.5 Kiloamp
221508	15 Amp	221702	2 Kiloamp
221509	20 Amp	221703	3 Kiloamp
221510	30 Amp	221704	5 Kiloamp
221511	50 Amp	221705	7.5 Kiloamp
221512	75 Amp	221706	10 Kiloamp
221513	100 Amp		

OTHER ACCESSORIES

Mounting hardware ..... order by description of meter
Conduit case for 21/2" Big Look ..... part no. 2579K10G0700
Antistatic solution in 31/2 oz. bottle ..... part no. 177001AAAA

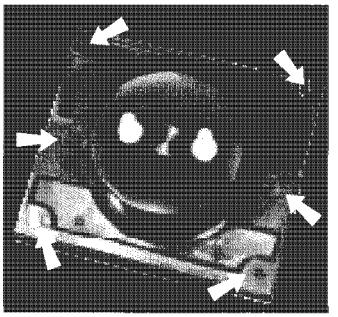
IP7014995

Features	New Big Look Horizon Line Panel Meters	Frequency and Expanded Scale Voltmeters	Stylist Series	185 and 280 Edgewise
1. Special Scales Any deviation from standard scale information on catalog listed items constitutes a special scale	X	X	X	X
2. Special color on scale (black on white-std) Each special color on scale constitutes one option	X	X	X	X
3. Mirror-back Scale includes knife-edge pointer (DC only)	X[1]	X[1]	X[1]	N/A
4. Nonlisted Rating	X	X	X	X
5. High-sensitivity voltmeters (DC only) Standard sensitivity for DC voltmeters is 1000 ohms/volt (1 milliamp current)	X	X	X	X
6. Suppressed-zero (DC only) (20% Suppression Max.) Suppressed-zero meters have greater error than standard zero-left meters. Normally suppressed-zero units are supplied with zero adjustment. They can be furnished with inoperable zero adjustment upon request.	X	N/A	X	X
7. Offset-zero ratings and scale (DC only)	X	N/A	X	X
8. Nonstandard lead resistance Standard two-way shunt lead resistance for shunt-rated ammeters, 50 or 100 millivolt, is 0.065 ohms. Normally these meters can be used with a wide range of lead resistances with only very small additional errors. However, if calibration for a specific value of lead resistance other than 0.065 ohms is required, contact factory.	X	N/A	X	X
9. Calibration for mounting at a specific angle Special calibration not required for meters mounted 0 to 19 degrees from vertical position.	X	X	X	X
10. Calibration for specific frequency, 25-400 Hertz. For calibration at frequencies greater than 400 Hertz, refer to factory	X	X[3]	X	X
11. Special terminal resistance Normally nonstandard terminal resistance requirements or close tolerance on terminal resistance should be referred to the factory.	X	N/A	X	X
12. Red Day-Glow pointer	X	X	X	X
13. Black scale with white or red pointer	X	X	X	X
14. Special case and cover material (Refer to factory on available materials).	X	X	X	X
15. Anti-glare window	X	X	X	X
16. ±1% FS accuracy at one point on scale. (±2% FS over balance of scale)	X	N/A	X	X
17. Extra Hardware	X	X	X	X
18. Double rated, 3 studs (including scale)	X	N/A	X	N/A
19. ±1% FS accuracy — all points on scale (DC with Mirror Scale — 3½ and 4½ H.L. & Stylist Only)	X	N/A	X	N/A
20. Tachometer Voltmeter (including scale, pot & special FSV)	X	N/A	X	N/A
21. Lead length compensation pot (Millivoltmeters)	X	N/A	X	N/A
22. UL 1437 Materials (2½-4½" only)	X	X	X	X
23. External Magnetic Shield (2½-4½" only) (Standard on AC Ammeters 20 amps or higher)	X[2]	N/A	N/A	N/A
24. IEC Standard 144 (IP54) (2½ & 3½ B.L. only)	X	X	N/A	N/A

X= Available
N/A = Not Available

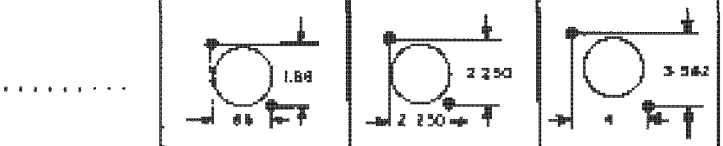
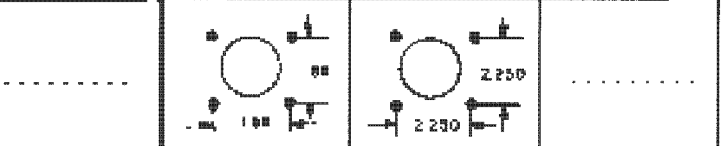
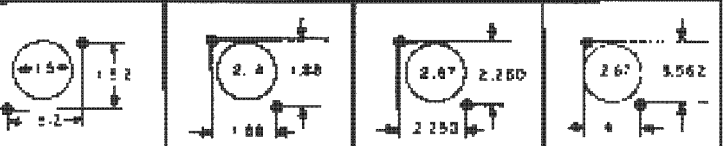
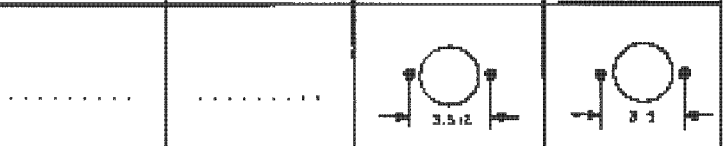
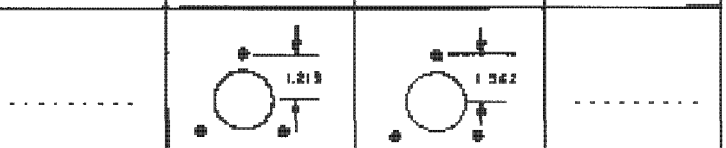
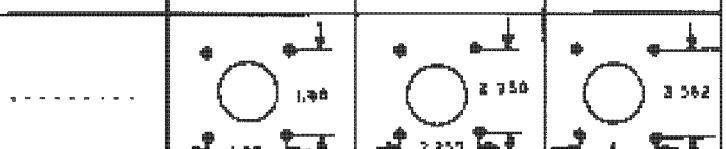
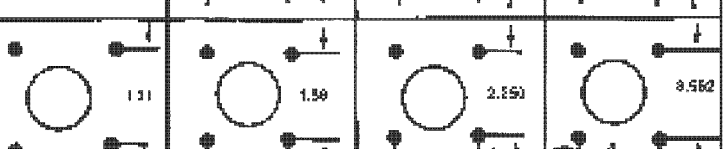
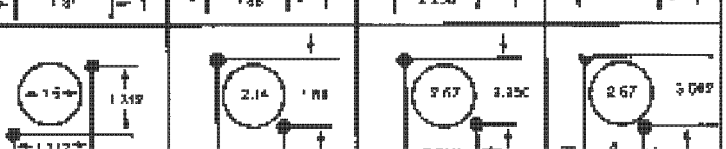
Note: 1. Stylist 2½"-4½", HL 3½"-4½"
2. Horizon Line and New Big Look Only
3. Expanded Scale Voltmeter Only

Mounting In Your Present Panel Openings . . .



Optional Front-Mounting Configurations

The mounting studs on the New Big Look, Horizon Line and Stylist Series Surface Mount can be ordered to fit your existing panel openings at no extra cost. These cases are interchangeable with a wide variety of competitive instruments. Optional stud-placement configurations are shown at right and a cross-reference of many replacement instruments are listed on the next page. This built-in interchangeability eliminates the need for drawing changes, setups, and redrilling of panels . . . and it solves your instrument replacement problems.

Stud Options	Barrel diameters and mounting hole locations (viewed from front of panel)			
	1½"	2½"	3½"	4½"
Standard New Big Look				
New Big Look Option No. 1	. . . . .			
New Big Look Option No. 2 (Similar to Option No. 1 location — used when 4 studs are wanted)	. . . . .			. . . . .
Standard Horizon Line				
Horizon Line Option No. 1	. . . . .	. . . . .		
Horizon Line Option No. 2	. . . . .			. . . . .
Horizon Line Option No. 3 (Similar to Standard location — used when 4 studs are wanted)	. . . . .			
Stylist Surface Standard				
Stylist Surface Option No. 1				

INTERCHANGEABILITY CROSS-REFERENCE (for front-of-panel mounting)

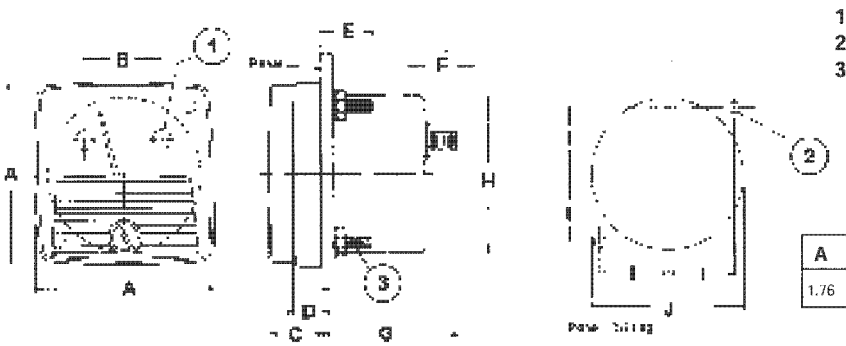
Interchangeable with:	New Big Look				Horizon Line				Stylist Surface Mount			
	1½"	2½"	3½"	4½"	1½"	2½"	3½"	4½"	1½"	2½"	3½"	4½"
Weston 1900	NI	Op1	Op1	S	NI	S	S	S	NI	Op1	Op1	Op1
Weston 201, 301 (square)	NA	Op1	Op1	NA	NA	S	S	NA	NA	Op1	Op1	NA
Weston 201, 301 (round)	NA	S	S	NA	NA	Op2	Op2	NA	CBD	CBD	CBD	CBD
Simpson 25, 125T, etc.	NA	S	S	S	NA	Op2	Op2	S	NA	NI	NI	Op1
Simpson 27, 127, etc.	NA	Op1	Op1	S	NA	S	S	S	NA	Op1	Op1	Op1
Honeywell MS, MM, 45, 55	NI	S	S	S	NI	Op2	Op2	S	NI	NI	NI	Op1
Triplett G, PL, M, 327, 337S, etc.	S	Op1	Op1	S	S	S	S	S	Op1	Op1	Op1	Op1
Triplett 221T, 331S, 351T, 420, etc.	NA	S	S	S	NA	Op2	Op2	S	NA	NI	NI	Op1
API Panelist	NA	NI	Op1	S	NA	NI	S	S	NA	NI	Op1	Op1
Westinghouse G	NA	Op1	NI	NI	NA	S	NI	NI	NA	Op1	NI	NI
Ammon, AM, AP	S	S	S	S	S	Op2	Op2	S	Op1	NI	NI	Op1
Beede, 3-01, 614, 23 etc.	NA	Op1	Op1	S	NA	S	S	S	NA	Op1	Op1	Op1
Hoyt Custom 2035	S	Op1	Op1	S	S	S	S	S	Op1	Op1	Op1	Op1
Hoyt 1035, 680, etc.	NA	S	S	S	NA	Op2	Op2	S	NA	NI	NI	Op1
Ideal 250P, K350P, 460P Imperial	NI	Op1	Op1	S	NI	S	S	S	NI	Op1	Op1	Op1
Ideal 275Pr, 305BR	NI	S	S	S	NI	Op2	Op2	S	NI	NI	NI	Op1
Simpson Wide-Vue	S	Op1	Op1	S	S	S	S	S	Op1	Op1	Op1	Op1
Modutec S, C	S	Op1	Op1	S	S	S	S	S	S	S	S	S
Modutec PB	CBD	S	S	CBD	CBD	S	S	CBD	S	NA	NA	S
Sun 2830, 3X, 25, etc.	NA	S	S	S	NA	Op2	Op2	S	NA	NI	NI	Op1
Mercer 924	CBD	CBD	CBD	S	CBD	CBD	CBD	S	CBD	CBD	CBD	Op1
Crompton 016 Fiesta	CBD	CBD	S	CBD	CBD	CBD	Op2	CBD	CBD	CBD	NI	CBD
Crompton 210, 223, 225, 227	CBD	Op1	Op2	S	CBD	S	Op3	Op3	CBD	Op1	S	S

Code:

S — Interchangeable with Standard pin configuration.
Op1 — Interchangeable with Option 1.
Op2 — Interchangeable with Option 2.
Op3 — Interchangeable with Option 3.
NI — Not interchangeable
NA — Not applicable (usually means particular size is not manufactured).
CBD — Cannot be determined.

YOKOGAWA ◆ Dimensional Drawings

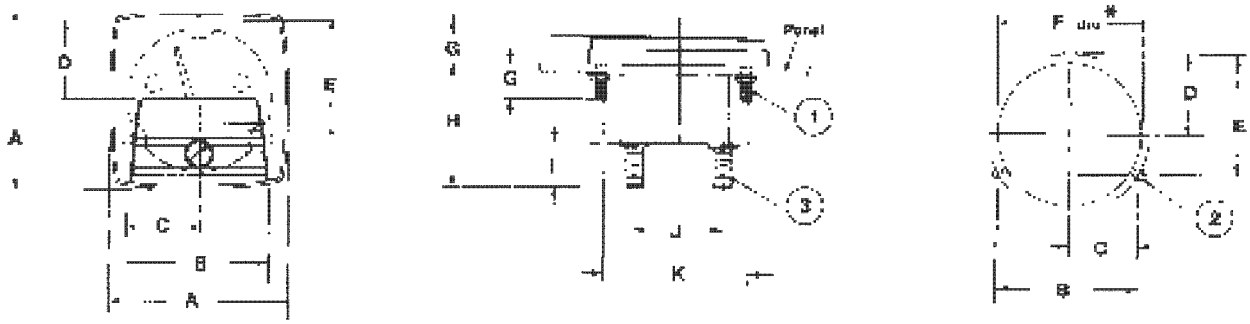
Fig. 1 New Big Look 1½ inch Type 250



1. **No. 8-32 NC 2A (2 term studs)**
2. **.140" dia. (No. 28) (2 holes)**
3. **N. 4-40 NC 2A (2 mounting studs)**

A	B	C	D	E	F	G	H	I	J
1.76	.75	.5	.25	.5	.38	1.34	1.5	.656	1.53

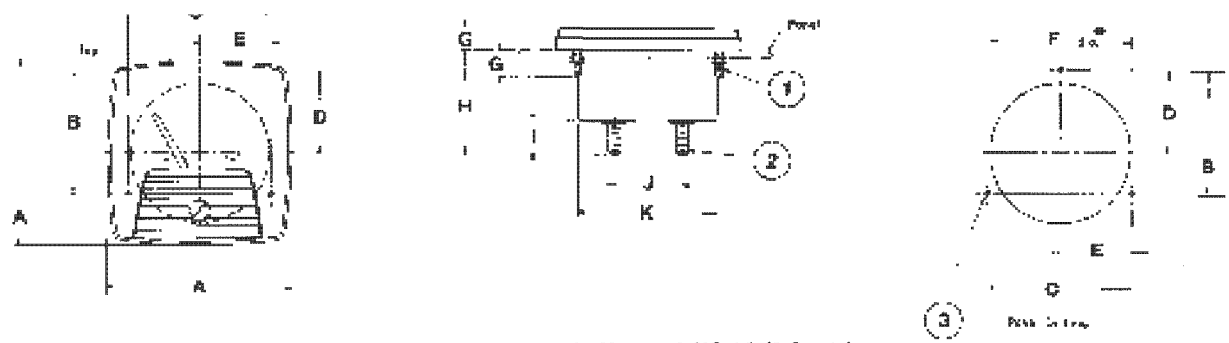
Fig. 2. New Big Look 2½-inch Types 250 & 254
*2.270 dia. with shield



A	B	C	D	E	F*	G	H	I	J	K
2.69	2.112	1.056	1.219	1.829	2.17	.5	1.85	.67	1.318	2.15

1. No. 4-40 NC 2A (3 Studs)
2. 140" dia. (No. 28) (3 holes)
3. 1/4" -28 NF 2A thd.

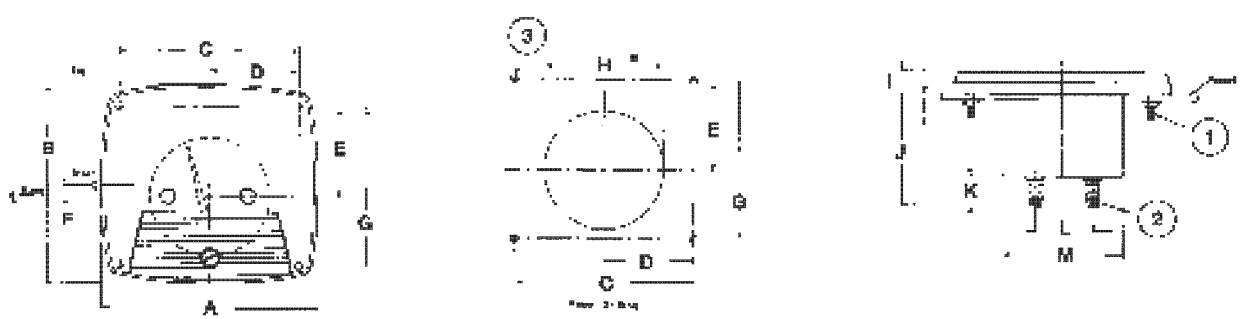
Fig. 3. New Big Look 31/2-inch Types 250 & 254
*2.860 dia. with shield



A	B	C	D	E	F*	G	H	I	J	K
3.5	2.373	2.74	1.582	1.37	2.72	.5	1.85	.64	1.318	2.7

1. No. 4-40 NC 2A (3 Studs)
2. ¼" - 28 NF 2A thd.
3. .140" dia. (No. 28 dr.) (3 holes)

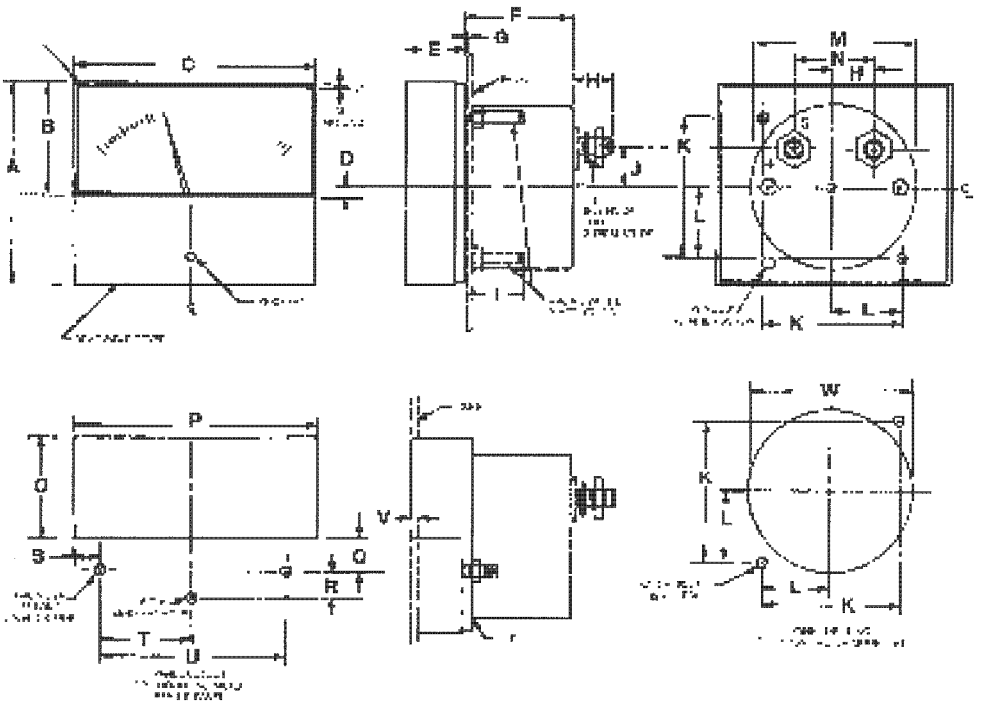
Fig. 4. New Big Look 41/2-inch Types 250 & 254
*2.860 dia. with shield



A	B	C	D	E	F	G	H*	I	J	K	L	M
4.85	4.41	4	2	2.031	.25	3.562	2.72	.5	1.85	.64	1.318	2.7

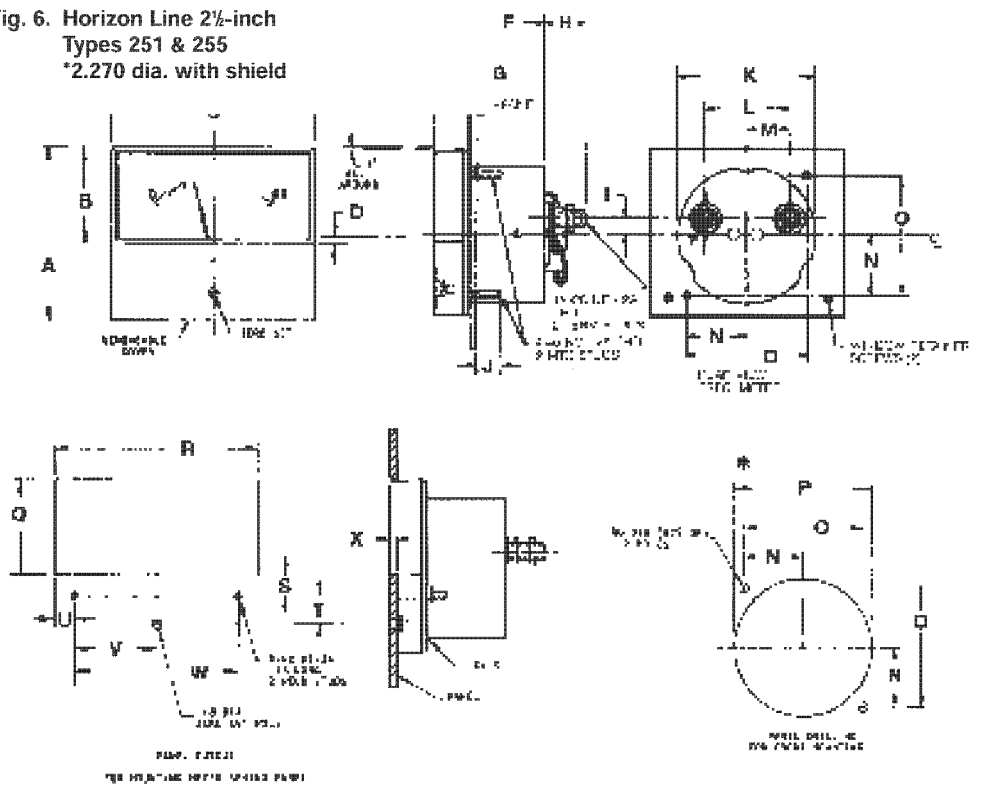
1. No. 4-40 NC 2A (4 Studs)
2. 1/4" - 28 NF 2A thd.
3. .140" dia. (No. 28 dr.) (4 holes)

Fig. 5 Horizon Line 1½-inch
Types 251 & 255



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1.86	1.036	2.19	.055	.5	.96	.008	.38	.5	.34	1.312	.656	1.510	.75	1.05	2.18	.356	.175	.24	.85	1.7	.06	1.53

Fig. 6. Horizon Line 2½-inch
Types 251 & 255
*2.270 dia. with shield



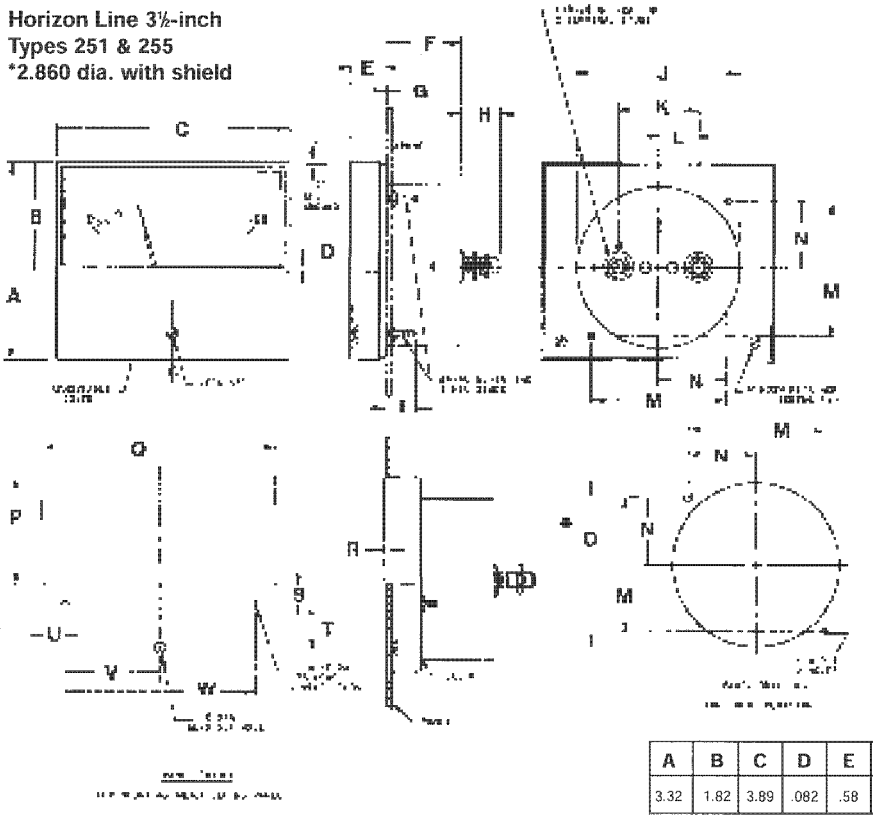
A	B	C	D	E	F
2.66	1.46	3.12	.072	.56	1.18

G	H	I	J	K	L
.088	.63	.26	.5	2.17	1.32

M	N	O	P*	Q	R
.66	.94	1.88	2.19	1.475	3.11

S	T	U	V	W	X
.296	.434	.305	1.25	2.5	.1

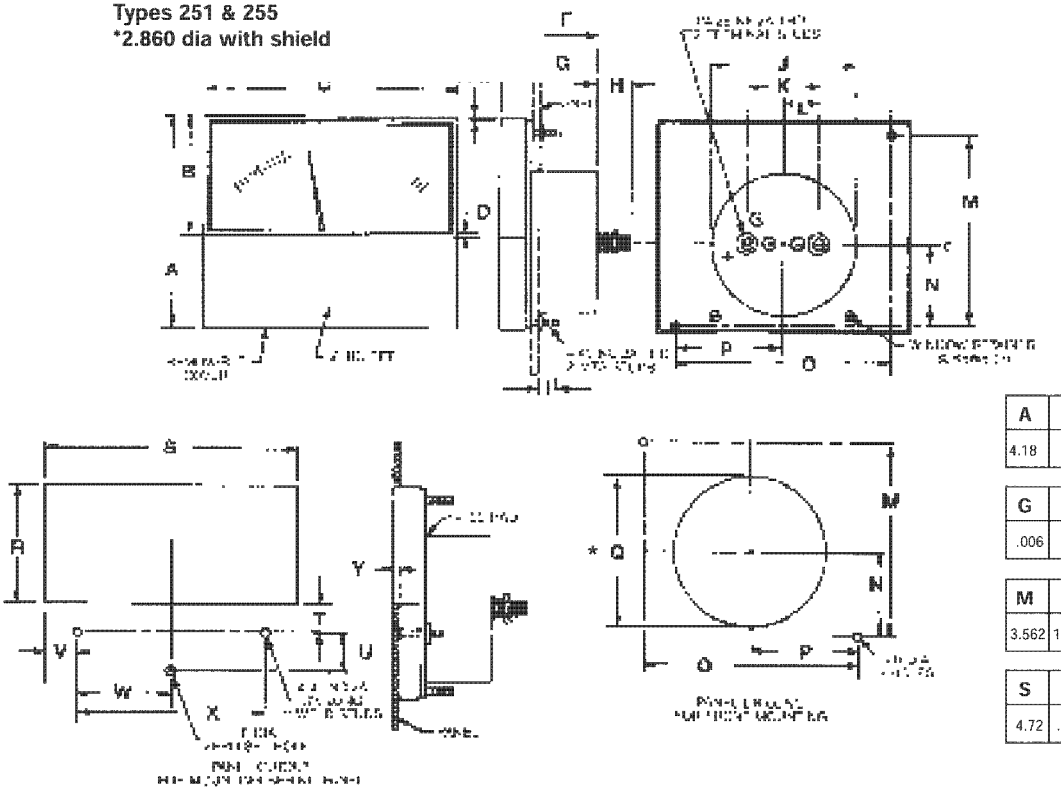
Fig. 7. Horizon Line 3½-inch
Types 251 & 255
*2.860 dia. with shield



A	B	C	D	E	F	G	H	I	J	K
3.32	1.82	3.89	.082	.58	1.2	.008	.63	.5	2.7	1.32

L	M	N	O*	P	Q	R	S	T	U	V	W
.66	2.25	1.125	2.72	1.836	3.88	.1	.296	.727	.360	1.578	3.156

Fig. 8. Horizon Line 4½-inch
Types 251 & 255
*2.860 dia with shield



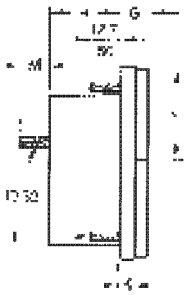
A	B	C	D	E	F
4.18	2.2	4.73	.12	.59	1.2

G	H	I	J	K	L
.006	.63	.5	2.7	1.32	.66

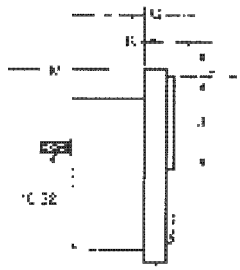
M	N	O	P	Q*	R
3.562	1.531	4	2	2.72	2.216

S	T	U	V	W	X	Y
4.72	.518	.702	.605	1.75	3.5	1

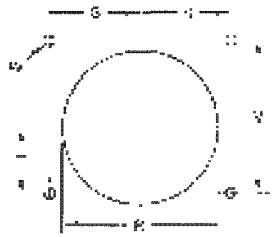
Fig. 9. Stylist Series
Types 260, 261, 264 & 265



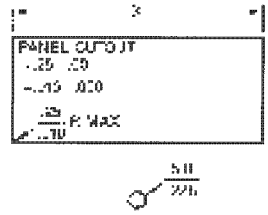
Surface Mount



Window Mount



Surface Mount Panel Cutout



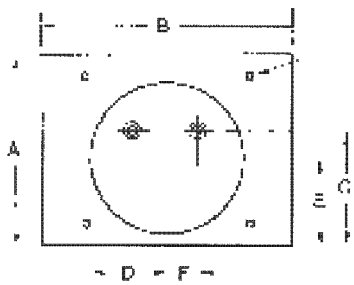
Window Mount Panel Cutout

SURFACE MOUNT METERS

		A	B	C	D	E	F	G	H	J	K	L	M	R	S	T	V	W
1½	in.	1.75	2.24	.99	.76	.83	.48	.34	1.30	.87	N/A	4-40	.25	.155	.66	.66	1.31	.125
2½	in.	2.27	2.99	1.33	1.07	1.13	.56	.40	1.30	1.24	N/A	4-40	.50	2.22	.94	.94	1.88	.125
3½	in.	2.87	3.70	1.44	1.33	1.44	.56	.41	1.30	1.55	N/A	4-40	.50	2.82	1.12	1.12	2.25	1.25
4½	in.	3.96	5.10	1.74	1.33	1.74	.56	.51	1.26	2.20	N/A	4-40	.50	2.82	2.00	1.54	3.56	.125

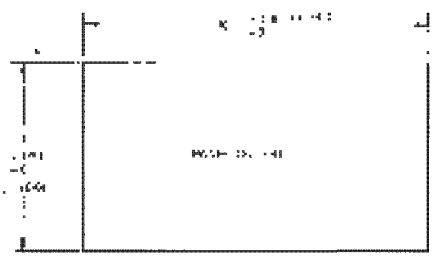
WINDOW MOUNT METERS

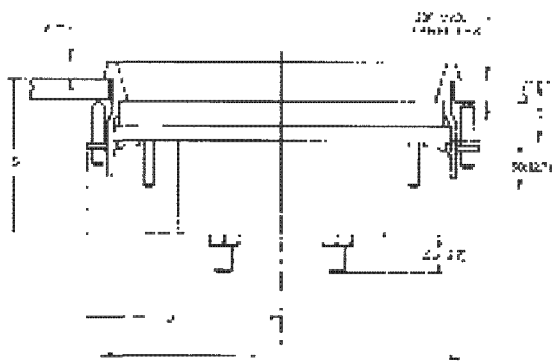
		A	B	C	D	E	F	G	H	J	K	L	M	X	Y	Z
2½	in.	2.29	3.01	1.35	1.06	1.15	.56	.295	1.30	1.260	.145	.06	.50	2.900	1.270	.633
3½	in.	2.90	3.73	1.45	1.33	1.45	.56	.32	1.30	1.585	.145	.07	.50	3.610	1.595	.804
4½	in.	4.60	5.18	1.79	1.33	1.79	.56	.37	1.26	2.335	.145	.09	.50	5.020	2.345	.856

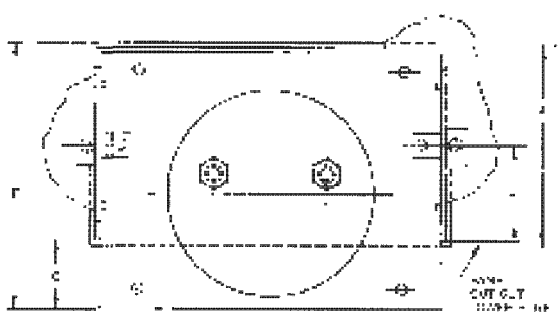


Surface and Winow Mount Meters rear view (combined)

Fig. 10. Bezel Mounts of Surface Mount Stylist Meters







		A	B	C	D	E
2½	in.	.13	1.87	.57	1.78	3.15
3½	in.	.14	1.89	.59	2.14	3.85
4½	in.	.12	2.05	.75	2.84	5.24

	F	G	H	J	K	L
2½	2.30	.64	.79	1.74	3.00	1.594
3½	2.94	.72	1.07	2.30	3.718	2.156
4½	4.05	1.13	1.42	2.99	5.126	2.843

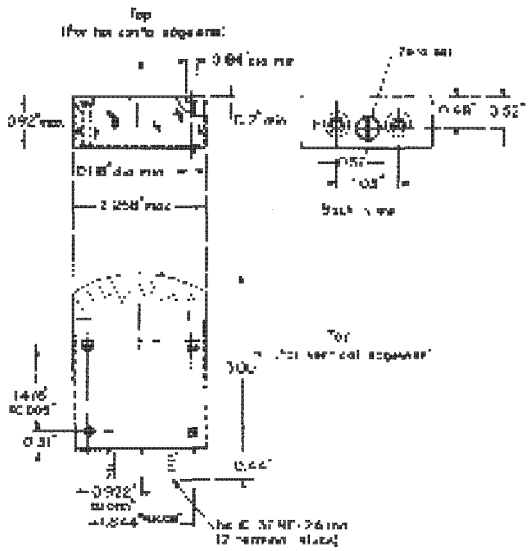


Fig. 11. Outline dimensions for Type 185 meters

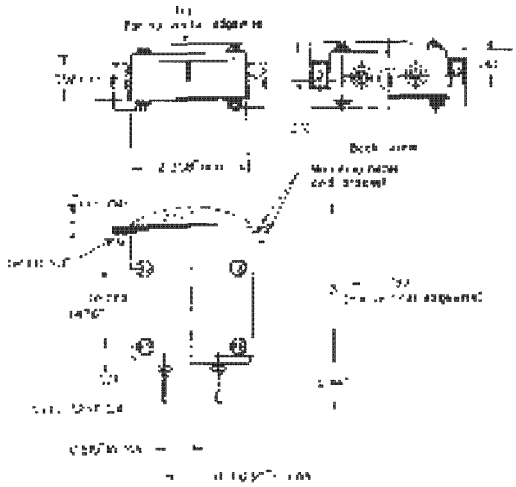


Fig. 12. Outline dimensions for Type 185 meter, with bezel and mounting bracket. See Fig. 15 & 16 below

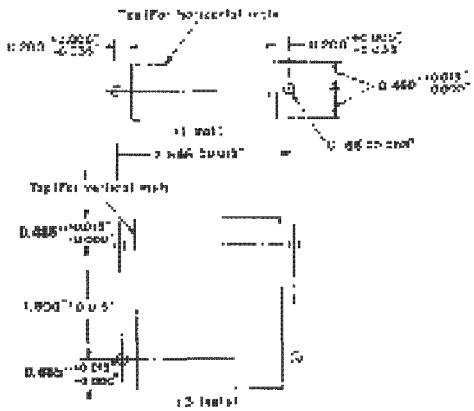


Fig. 13. Panel cutout dimensions for mounting 1 or 3 meters, with bezels and mounting brackets

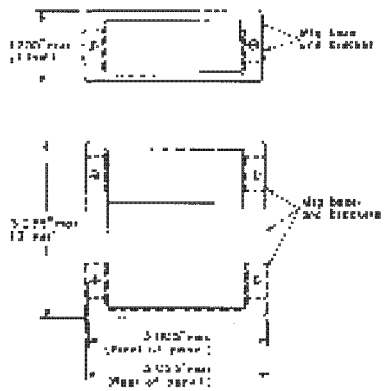


Fig. 14. Dimensions of bezels

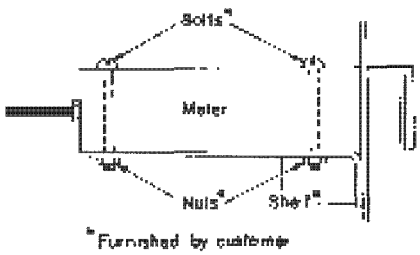


Fig. 15. Mounting of Type 185 meter on back of panel equipment

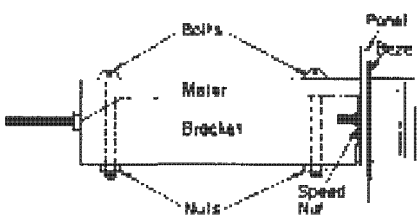
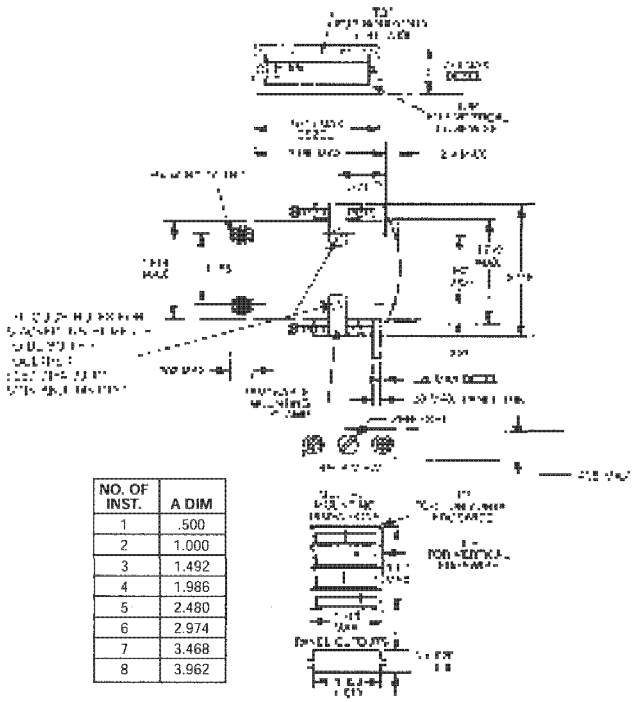
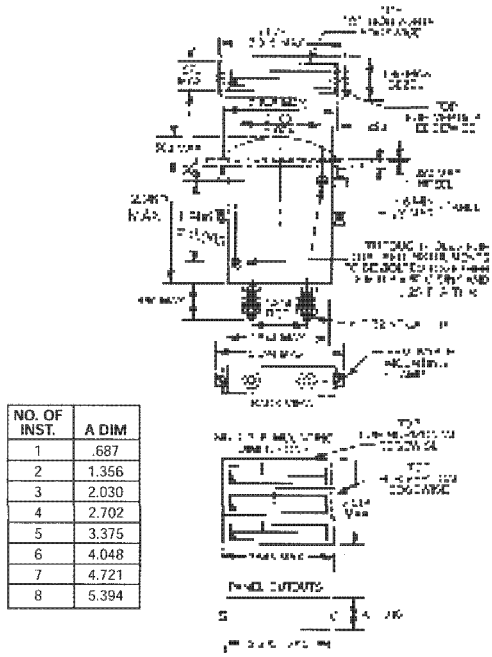


Fig. 16. Type 185 meter with bezel mounting bracket and hardware



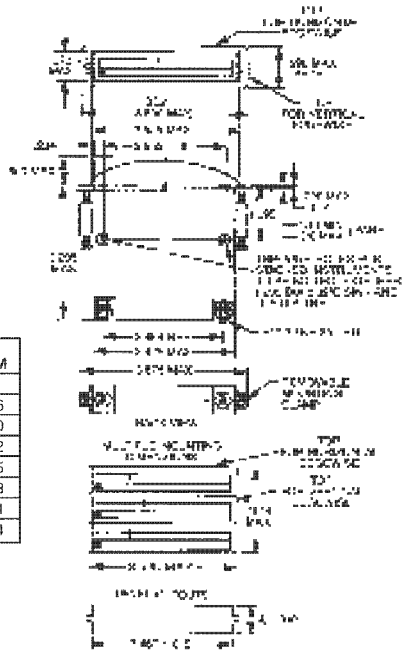
NO. OF INST.	A DIM
1	.500
2	1.000
3	1.492
4	1.986
5	2.480
6	2.974
7	3.468
8	3.962

Fig. 17. Outline Dimensions for 1½-inch Type 286 meters



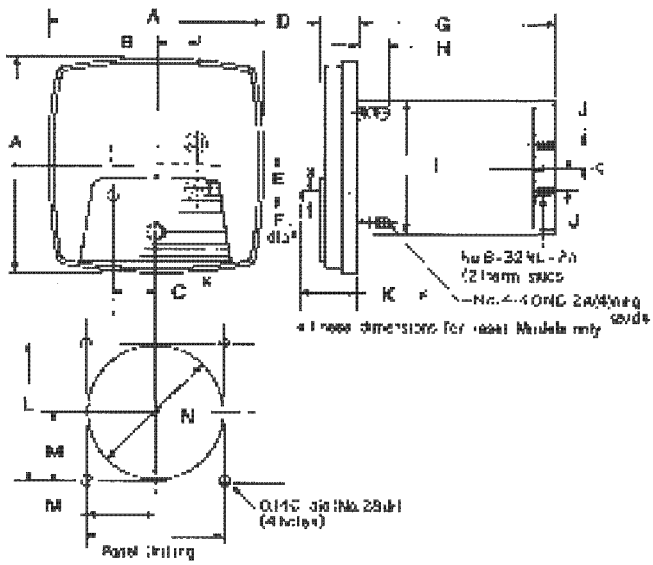
NO. OF INST.	A DIM
1	.687
2	1.356
3	2.030
4	2.702
5	3.375
6	4.048
7	4.721
8	5.394

Fig. 18. Outline Dimensions for 2½-inch Type 287 meters



NO. OF INST.	A DIM
1	.687
2	1.356
3	2.030
4	2.702
5	3.375
6	4.048
7	4.721
8	5.394

Fig. 19. Outline Dimensions for 3½-inch Type 288 meters



SIZE \ DIM	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2½ BL	2.7	.68	.72	.5	.48	.14	3.253	.5	2.215	.38	.80	1.88	.94	2.22
3½ BL	3.5	.68	.72	.5	.48	.14	3.253	.5	2.215	.38	.80	2.25	1.125	2.22

Fig. 20. New Big Look 2½ & 3½-inch Type 240

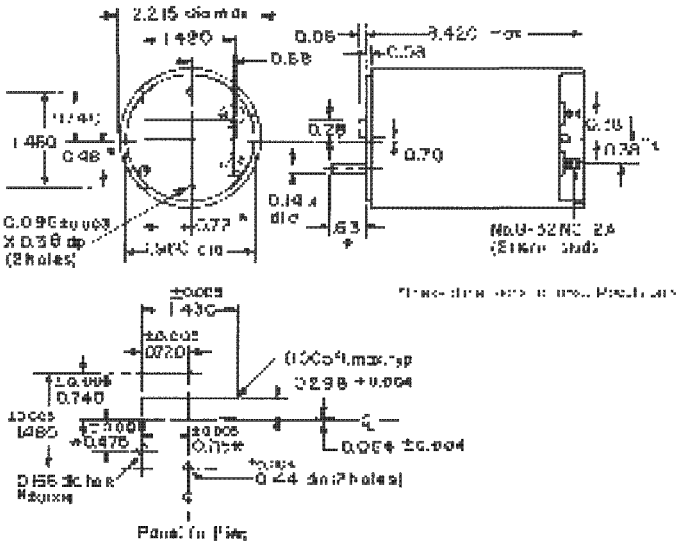
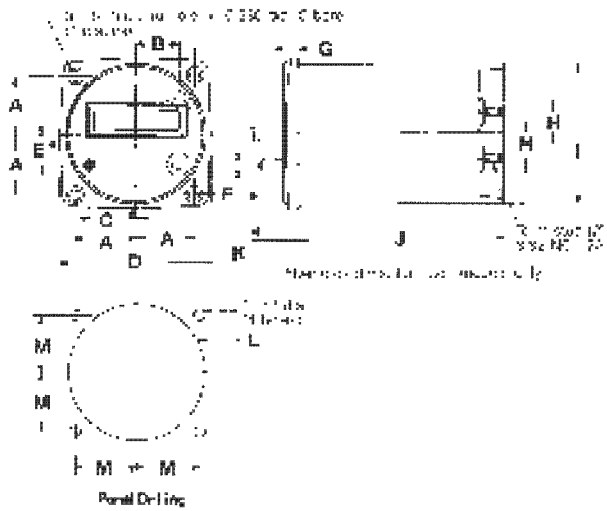
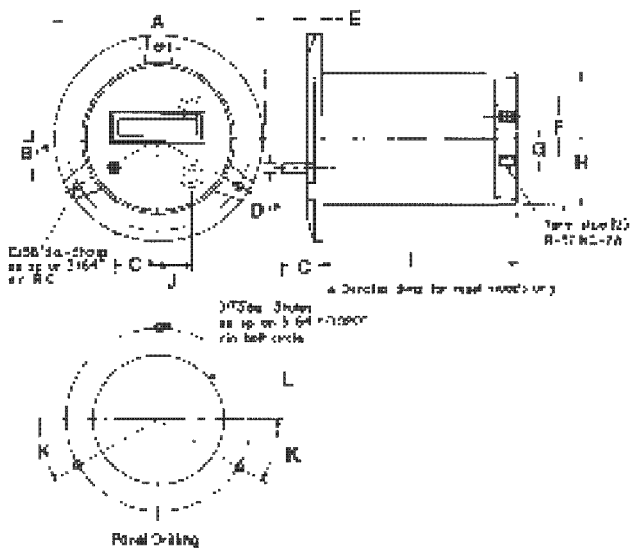


Fig. 21. Type 240 Back-of-panel model



SIZE \ DIM	A	B	C	D	E	F	G	H	I	J	K	L	M
2½ BL	.94	.68	.72	2.38	.48	.14	.25	.38	2.215	3.286	.76	2.22	.94
3½ BL	1.12	.68	.72	3.0	.48	.14	.25	.38	2.215	3.286	.76	2.22	1.125

Fig. 22. Type 240 square case



SIZE \ DIM	A	B	C	D	E	F	G	H	I	J	K	L
2½ BL	2.68	.48	.72	.14	.21	.38	.38	2.215	3.33	.68	30°	2.22
3½ BL	3.51	.48	.72	.14	.22	.38	.38	2.215	3.32	.68	30°	2.22

Fig. 23. 2½-3½-inch Type 240 round case

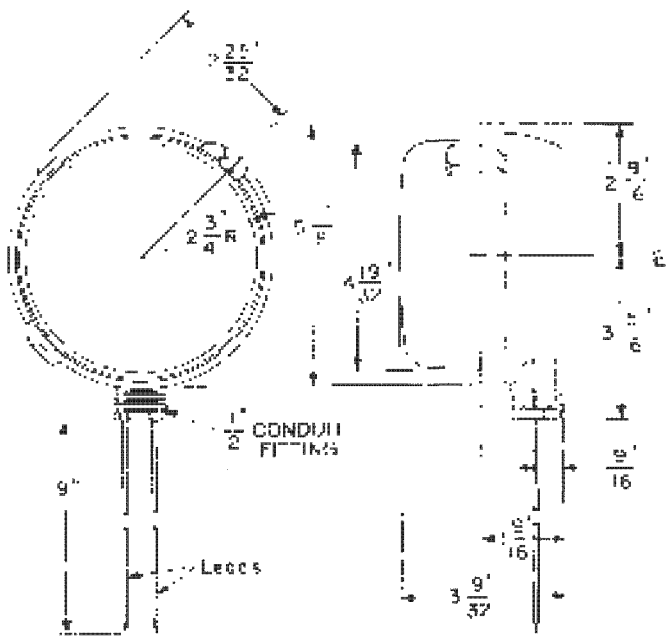
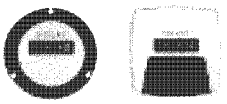
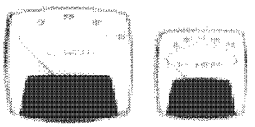


Fig. 24. Type 240 conduit-mounted case

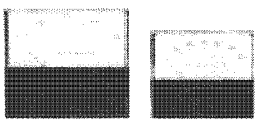
PANEL METERS



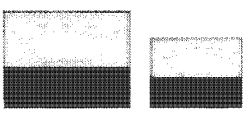
Elapsed Time Meters



New Big Look Panel Meters

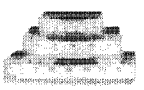


Horizon Line Panel Meters



Stylist Panel Meters

Type 185 Edgewise Meters



Type 280 Thin Edgewise Meters

YOKOGAWA

Yokogawa Corporation of America

2 Dart Road
Newnan, GA 30265
770/253-7000 • 770/251-2088 (FAX)
800/258-2552 x 575
www.yca.com

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ALSTOM

SIGMA CONTROLLER

TECHNICAL MANUAL

SIGMA.TM Issue F
17 August 2000

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ALSTOM Power Conversion Ltd

IP7015007

IP7015008

FOREWORD

The operating and maintenance information contained herein is intended as a guide for the personnel responsible for running the plant and should be used to supplement approved operating and maintenance techniques.

If any further information is required communicate with the Branch Office (Local Agents) or direct with:

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HEALTH AND SAFETY

A drive system incorporating the SIGMA controller is not intended for direct control of safety critical systems. All safety circuits must be hardwired and operated independently of the SIGMA controller.

Every installation using the SIGMA controller should include a safety risk analysis as part of the contract safety file (where applicable).

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SCOPE OF MANUAL

This document specifies the operation of the SIGMA Controller. It is intended mainly as a programming resource for the SIGMA core. Other documents that should be read in conjunction with this document are:

- CSP Programming Manual
- Customer I/O board Specification
- The applicable Power Interface Board Specification for the contract
- SIGMA Application module specifications
- SIGMA Special function specifications

The SIGMA core board type supported is the 20X4494 board, which uses firmware databases in the GDS1106-xxxx range.

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CONTENTS

FOREWORD i

HEALTH AND SAFETY ii

SCOPE OF MANUAL iii

CONTENTS iv

1. INTRODUCTION 1-1
   - 1.1 BLOCK DIAGRAM 1-1
   - 1.2 FEATURES 1-3
   - 1.3 SUMMARY 1-4
   - 1.4 DIGITAL I/O 1-6
     - 1.4.1 Introduction 1-6
     - 1.4.2 Digital Inputs 1-6
     - 1.4.3 Digital Outputs 1-7
     - 1.4.4 Watchdog Relay 1-7
     - 1.4.5 Basic I/O 1-7
     - 1.4.6 Incremental Encoder 1-8
     - 1.4.7 Encoder Interface Board 1-9
   - 1.5 ANALOG I/O 1-10
     - 1.5.1 Analogue Inputs (12 bit) 1-10
     - 1.5.2 Analogue Inputs (10bit) 1-10
     - 1.5.3 Analogue Outputs (include scope outputs) 1-11
   - 1.6 SERIAL LINKS 1-12
     - 1.6.1 Introduction 1-12
     - 1.6.2 Serial Link 0 1-13
     - 1.6.3 Serial Link 1 1-15
     - 1.6.4 Serial Link 2 1-15
     - 1.6.5 Serial Link 3 1-16
     - 1.6.6 Using ESP J/K Table Exchange 1-17
     - 1.6.7 Using MODBUS 1-18
     - 1.6.8 Serial Link Fault Diagnostics 1-19
     - 1.6.9 ESP Programming Messages 1-20
     - 1.6.10 Connection Details 1-21
   - 1.7 ENHANCEMENT CARDS 1-22
     - 1.7.1 Connections 1-22
     - 1.7.2 Configuration 1-22
   - 1.8 MISCELLANEOUS FACILITIES 1-23
     - 1.8.1 Board OIS Data 1-23
     - 1.8.2 OIS Protection 1-24
     - 1.8.3 Calendar Clock 1-24
     - 1.8.4 Miscellaneous Timing functions 1-25

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1.9 BATTERY 1-25

2. FIRMWARE DATABASE 2-1

2.1 INTRODUCTION 2-1

2.2 EXECUTION SEQUENCE 2-1
2.2.1 BOOT EEPROM 2-1
2.2.2 Initialise System 2-1
2.2.3 Execution Cycle 2-2
2.2.4 Messaging Stage 2-3
2.2.5 End of Execution Cycle 2-4
2.2.6 Execution Scan Time 2-4

2.3 HALT/RUN STATUS 2-5
2.3.1 RUN Conditions 2-5
2.3.2 Power Up Conditions 2-6
2.3.3 HALT Conditions 2-6
2.3.4 Monitoring 2-6

2.4 OTHER MODES 2-7
2.4.1 Test/Normal Status 2-7
2.4.2 Commissioning Mode 2-7

2.5 SUPPLY CHECKS 2-8
2.5.1 Analogue Supplies 2-8
2.5.2 Battery Monitor 2-8
2.5.3 Early Power Fail (A35.2) 2-8

2.6 FLASH PROGRAMMING 2-9
2.6.1 Summary 2-9
2.6.2 Restoring Program From FLASH 2-9
2.6.3 Issues to Note With Batteries Not Fitted 2-10
2.6.4 Parameters 2-10
2.6.5 Monitoring 2-10
2.6.6 Control 2-10
2.6.7 Errors 2-10
2.6.8 Program and Run 2-11
2.6.9 Loss of Power When Programming Flash 2-11

2.7 WATCHDOG 2-12
2.7.1 Watchdog OK LED 2-12
2.7.2 Watchdog Circuit 2-12
2.7.3 Watchdog Start Up Checks 2-12
2.7.4 Checks When Running 2-13
2.7.5 Watchdog Error Codes 2-13

2.8 DOWNLOADING A NEW SYSTEM 2-14

3. APPLICATION SOFTWARE 3-1

3.1 INTRODUCTION 3-1

3.2 SOFTWARE MODULES 3-1

3.3 LINKS PROGRAM 3-2
3.3.1 Header 3-2

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3.3.2 The Links Program 3-4
3.3.3 DEF TABLE Command 3-5

3.4 LADDER PROGRAM 3-6
3.4.1 General 3-6
3.4.2 Serial Link Configurations 3-6
3.4.3 Invoking Software Modules 3-7
3.4.4 Logic Requirements 3-7
3.4.5 Ladder Instructions 3-7
3.4.6 Special Functions 3-8

4. USER INFORMATION 4-1

4.1 KEYPAD 4-1
4.1.1 Keypad Diagram 4-1
4.1.2 Introduction 4-1
4.1.3 Menu Summary 4-2
4.1.4 LED Indicators 4-2
4.1.5 Monitoring and Editing Drive Parameters 4-3
4.1.6 Control Keys 4-3
4.1.7 Alphanumeric Keys 4-3
4.1.8 Digital Inputs/Outputs 4-4
4.1.9 User Configuration 4-5
4.1.10 Serial Link Failure 4-5
4.1.11 Display Format 4-6
4.1.12 Functions of the Keypad 4-7
4.1.13 Scope Output 4-12
4.1.14 Keypad Error Messages 4-12

4.2 CSP 4-13

4.3 MESSAGES AND INDICATIONS 4-14
4.3.1 Warning Messages 4-14
4.3.2 SIGMA Core LED's 4-15
4.3.3 Seven Segment Display Indicators 4-15

4.4 WATCHDOG TRIP NUMBERS 4-17
4.4.1 Catastrophic Watchdog Failure 4-26

4.5 DATA TABLES 4-27
4.5.1 Introduction 4-27
4.5.2 Data Table Addressing 4-27
4.5.3 SIGMA Data tables (L Tables) 4-27
4.5.4 Other Data Tables 4-28
4.5.5 Values 4-28
4.5.6 Attributes 4-29
4.5.7 Access Levels 4-29
4.5.8 Table Allocation 4-30
4.5.9 Data Table Protection 4-30
4.5.10 Data Table Initialisation 4-31
4.5.11 Data Table Updating 4-31
4.5.12 Table Summary 4-32
4.5.13 A/B Tables 4-33

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4.5.14 C/D Tables 4-35
4.5.15 E Table 4-36
4.5.16 F Table - System Fault Table 4-38
4.5.17 I Table 4-39
4.5.18 J/K Serial Link Table 4-39
4.5.19 P Table 4-39

5. ORDERING DETAILS 5-1

5.1 SIGMA CORE 5-1

5.2 CUSTOMER I/O BOARD 5-1

5.3 ENHANCEMENT CARDS 5-1

5.4 POWER INTERFACE BOARDS 5-2

5.5 BASIC I/O BOARDS 5-3

5.6 OTHER PERIPHERAL BOARDS 5-3

5.7 POWER SUPPLY UNITS 5-3

6. CUSTOMER SUPPORT 6-1

7. GLOSSARY 7-1

8. INDEX 8-1

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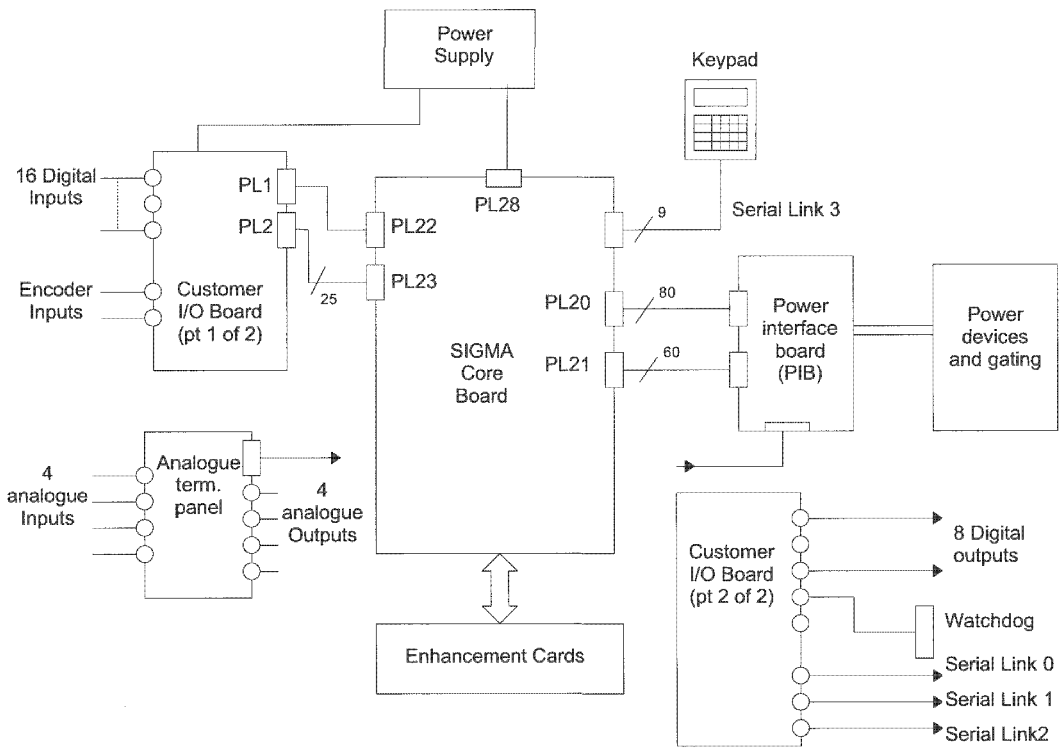
1. INTRODUCTION

1.1 BLOCK DIAGRAM

Figure 1-1 - Typical SIGMA system and components



The SIGMA Controller comprises:

- SIGMA Core Board
- Customer I/O Board
- Analogue Termination Panel
- Power Supply

The SIGMA controller uses microprocessors to provide flexible and accurate digital control of drives. The performance of the controller is such that it is suitable for other high performance control schemes.

The functions of the controller for power semiconductor fed drives is to provide firing pulses for all types of drive, both a.c. and d.c. Control available logic, sequencing, and remote communication functions are included. Software enables the controller to be configured for the type of d.c. and a.c drive required.

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A typical (d.c.) drive controller consists of the following main components (see Figure 1-1- Typical SIGMA system and components)

a) The Power Supply
b) The SIGMA Core Controller, which contains the processor electronics and optionally the keypad unit
c) The Customer I/O Board which provides the interface to the plant
d) *Analogue Termination Board*
e) The Power Interface Board which provides the interface to the Power Convertor This may be attached to the rear of the SIGMA Core Moulding
f) Power Board which is associated with certain power convertor types

Items a) to d), being known as the SIGMA Controller.

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1.2 FEATURES

- Comprehensive and flexible set of control functions
- Different combinations of the SIGMA Controller and the various power interface boards available, covers many applications
- High performance, zero drift digital control
- Built in commissioning and test facilities
- Built in first fault discrimination and history recording
- Serial communications to other controllers and programming unit

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1.3 SUMMARY

Power Interface Board
- Wide range of interface boards for: d.c. drives and a.c. drives such as PWM (Pulse Width Modulated), SYNCDRIVE, IMDRIVE, CYCLO (Cyclo-Convertor) etc.

Digital I/O
(Via Customer I/O Board)
- 16 digital inputs
- Watchdog output (relay)
- 8 digital outputs (via dedicated Basic I/O)

Analogue I/O
(Via Analogue Termination Panel)
- 4 Customer inputs provided via analogue termination panel. Main plant feedbacks (volts, current etc.) provided as part of the Power Interface Board
- 4 outputs

Encoder
- 5 differential inputs that can be configured via module 20

Serial Links
- 4 serial links for communication / programming
- ESP or MODBUS RTU or MODBUS ASCII available

Basic I/O
- 1 GEM80 standard BASIC I/O ribbon. Further I/O can be added using this facility

Enhancement Interface
- 4 slots for special cards (e.g. HDLC Serial Comms card, FIP card, OPTOLINK card)

Miscellaneous facilities
- Status lights on Keypad & Display
- Information on board build status and type available to user
- Battery maintained Clock and calendar facilities

Application Software
- Can be used with a wide range of power stacks.

- Set of pre-written control modules. Includes:
    - Voltage spillover control
    - Speed and position measurement and control
    - Reference ramp
    - Control available and control on logic
    - Comprehensive diagnostics with history recording

- User written links program to join modules and set parameters

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- User written ladder program to invoke control modules and implement logic functions

User interface
- Moveable keypad for parameter adjustment and monitoring
- PC based programmer for link and ladder programming, monitoring, and program load, CSP, OVERVIEW
- Status lamps on front of keypad

System software
- Independent check on micros (watchdog circuit)
- Self check of memory, supplies, interlocks
- Software Drivers for hardware I/O, enhancement boards

Processors
- Serial Comms processor for handling the serial links
- Control processor for all aspects of control

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1.4 DIGITAL I/O

1.4.1 Introduction

SIGMA digital I/O is provided by:

- Direct I/O via the Customer I/O Board
- BASIC I/O. The Customer I/O Board has some Basic I/O digital inputs and outputs built in. Further I/O can be provided by using GEM80 Basic I/O external subracks, or by using SIGMA BASIC I/O units
- Watchdog relay output (volt free) via Customer I/O Board

Since Basic I/O has a comparatively slow response time (dictated by the scan time of the Basic I/O driver), the direct inputs are provided. These can be used for inputs that are critical to the application. No direct outputs are provided except for a dedicated watchdog output, driving a relay on the customer I/O board. This can be used as an external interlock if required by the application engineer.

Connections to SIGMA are as shown in Figure 1.1.

For further details and connections see the Customer I/O Board Product Data.

1.4.2 Digital Inputs

16 digital inputs are provided via the Customer I/O Board.

On state	20V - 70V
Off state	5V maximum
Off state Leakage	0.5mA for off state
Hardware response time	1 ms.
Address Allocation	
A32.0 - A32.7	These data table inputs are read every user scan (typically 2 to 4.5ms), with a 'debounce time' of 1 scan (i.e. the input must be stable for two or more scans to have any effect). The inputs can also be read by the fast task at a rate determined by the fast task interrupt time. Note: A32.7 also provides a hardware pulse enable facility. 1 = Enable pulses 0 = Inhibit pulses
A1.0 - A1.7	Read by the Basic I/O. The update rate is dependant on the basic I/O scan (see "Update Rate" in section 1.4.5). The update of inputs is indicated by E0.10 = 1 (set on for one scan). All inputs are updated at the same time.

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1.4.3 Digital Outputs

There are 8 digital outputs via the Customer I/O Board. The load is applied between the output and digital 0V.

Voltage range	20-70V
Max. Volts (transient)	150V
Max off state leakage	1mA
Output current	250mA
Volts drop for on state	2.5V @ full load
Address allocation	
B1.8 - B1.15	The update rate of these outputs is dependant on the Basic I/O scan. They are updated at the end of the scan preceding E0.10 = 1

Note:
These outputs are short-circuit protected and are reset by:
- Interrupting the plant supply
- Disconnecting the load
- Setting the output off

1.4.4 Watchdog Relay

The watchdog is used to indicate a fault in the SIGMA hardware/firmware. It must NOT be used as the prime means of protection of either plant or personnel. See section 2.7 for further details on the function of the watchdog.

Output	Normally open volt free contact. Contact closed for watchdog healthy
Contact rating	250V ac @ 1A 100V dc @ 1A

1.4.5 Basic I/O

A BASIC I/O 26 way ribbon connects the core board to the Customer I/O Board (PL2). A further connector is provided on the Customer I/O Board (PL3) to allow a BASIC I/O subrack(s) from the GEM80 range, or M79/M80 Digital Output/Input Units, to be connected to the drive. This provides facilities for expanding the Analogue and Digital I/O by up to 224 Basic I/O points (14 words x 16 bits).

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Update Rate

The A and B tables are read by the I/O processor independently of the user scan. It is therefore possible that the basic I/O is updated at a slower rate than the user scan (typical 5 to 10ms to update the inputs compared with a user scan of 2 to 4.5ms). A flag (E0.10) is available to the user to indicate when the inputs have been updated and the outputs written out. Note that there may be a delay of up to one Basic I/O scan between E0.10 going on and the hardware output changing.

Configuration

Basic I/O is configured by referring to the table in the Ladder or Links file. If the table is not referenced in the user program, then it will not be read or written. (Except A1.0 to 7 and B1.8 to 15, which are a special case).

If the same address is used for both input and output then the Drive Compiler should flag up an error. The SIGMA system will not configure any of the Basic I/O if the input/output addresses clash.

Addresses

A/B 2.0 to A/B 15.15

Basic I/O Safety Checks

Various integrity checks are performed on the basic I/O, including address checking and data cross checking on certain bits in B1. These are covered in more detail in 'F1=14' of the watchdog fault codes, section 4.4.

1.4.6 Incremental Encoder

Five incremental encoder channels (inputs) are provided via the Customer I/O Board.

- Two inputs are required for a bi- phase speed/position feedback device
- Three inputs are required for a bi- phase + marker feedback device
- One input is required for a single phase speed feedback device

No. of Channels	5 (Marked A, B, C, D, E)
Signal	5V RS422 levels
Range	Max encoder frequency: 500kHz
Configuration	Via SIGMA application module 20

Note that the Customer I/O Board provides a 12V, 5V and 0V supply for use with an encoder.

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Firmware note:

The software driver necessary to read the encoders is provided by the SIGMA application module 20. See the Product Data sheet for this module for configuration information.

The incremental encoder input is conditioned by a XILINX programmable chip on the SIGMA Core Board, which is programmed from L20.

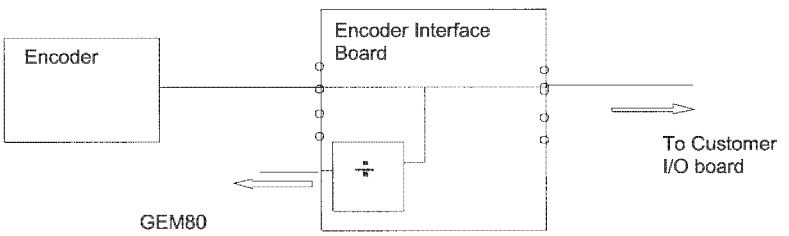
Connections
Connections to the encoder are as defined in the Customer I/O Board Product data, and the product data for module 20. Note that the full set of encoder inputs was only supported from module 20V3 onwards.

1.4.7 Encoder Interface Board

Connections to the Customer I/O Board may be via an Encoder Interface Board. This enables the encoder signals also to be used by another device such as a GEM80.

See section 5 for ordering details.

Figure 1-2 Encoder Interface Board



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1.5 ANALOG I/O

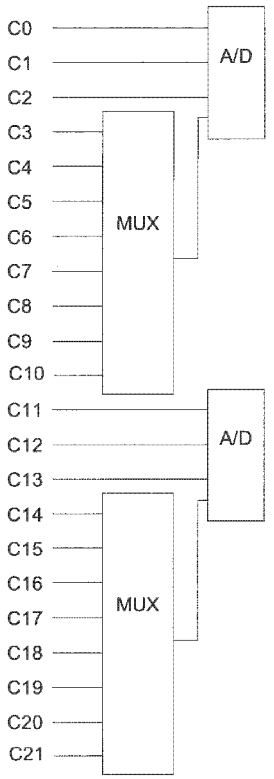
The following analogue I/O is provided via the
- 4 customer analogue inputs
- 4 customer analogue outputs

Current, volts feedbacks etc. are handled by dedicated inputs on the Power Interface Board. Power supply monitoring is handled by dedicated inputs on the SIGMA Core Board.

All inputs are sign extended to 32 bits for internal working.

The SIGMA core board provides 2 off 4 input, 12 bit A/D convertors together with 10 off 10 bit inputs to the I/O processor.

Figure 1-3
Analogue inputs



1.5.1 Analogue Inputs (12 bit)

For each 12 bit convertor, 3 inputs are read directly, the fourth is fed by an 8 input multiplexer. (See Figure 1-3). The actual inputs used depend on the Power Interface Board (PIB). For further details, see the relevant PIB product data.

Some inputs are dedicated to supply monitoring. The rest are fed from the Power Interface Board as single ended inputs. The Power Interface Board is responsible for isolation and conditioning of the inputs.

For further details on data table allocation and power supply monitoring see Section 4.5.14.

Resolution	11 bits + sign	
Range	+32767 = +10V; -32768 = -10V	
Addresses	C0 - C21	
Update rate	Determined by the interrupt rate of the fast task. Inputs C0-C2, C11-C13 and one multiplexed input on each A/D read each fast task interrupt. All 21 inputs should be read within 2 to 3ms.	
Data integrity	Word integrity	
Dedicated inputs	Table	Measures
	C10	0V
	C21	5V

1.5.2 Analogue Inputs (10bit)

10 inputs provided via the I/O processor. These inputs are used for supply monitoring.

Resolution	10 bits unsigned
Allocation	C22-C31 See section 4.5.14

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1.5.3 Analogue Outputs (include scope outputs)

Analogue outputs that are not used for plant interface can be configured as scope outputs for monitoring internal variable values. The configuration may be set by CSP in the Monitor mode, or as a links edit or using the keypad. See section 4.1.13 for more details on selecting variables as scope outputs via the keypad.

Signals	±10 V @ 5mA, short circuit proof
Source resistance	10 ohms
Addresses	D0 to D3 D4 - D7 are also available if the appropriate Power Interface Board is fitted (e.g. Type 'C' PIB)
Resolution	11 bits plus sign (approx. +/- 0.05%)
Range	+32767 = +10 V out; -32768 = -10 V out
Scope Output	Scope outputs may be configured from the PC by setting up the data table addresses in the E tables. See section 4.5.15, E22 - E24 for details.

Scope outputs can only be selected if the selected D table is not being used by either the user program or the fast task. (The Drive compiler sets a configuration table to indicate use, as does the fast task).

If an analogue output is not available as a scope output then a warning is displayed "Output Dn in use." This displays for 5 seconds and then clears. The relevant E table is cleared at the same time.

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1.6 SERIAL LINKS

1.6.1 Introduction

Three main serial links are provided via the communications processor on the SIGMA Core Board. A further serial link is provided to the local keypad and display unit.

Link 0 is used for programming, and is configured using SW1 on the Customer I/O Board. Alternatively it may be configured using the special function T33, as given in section 3.4.6.

Link 1 can be used as a general purpose communication port, providing ESP table exchange, programming and printer facilities. It can act as a master to up to 4 tributaries, with baud rates up to 76.8k.

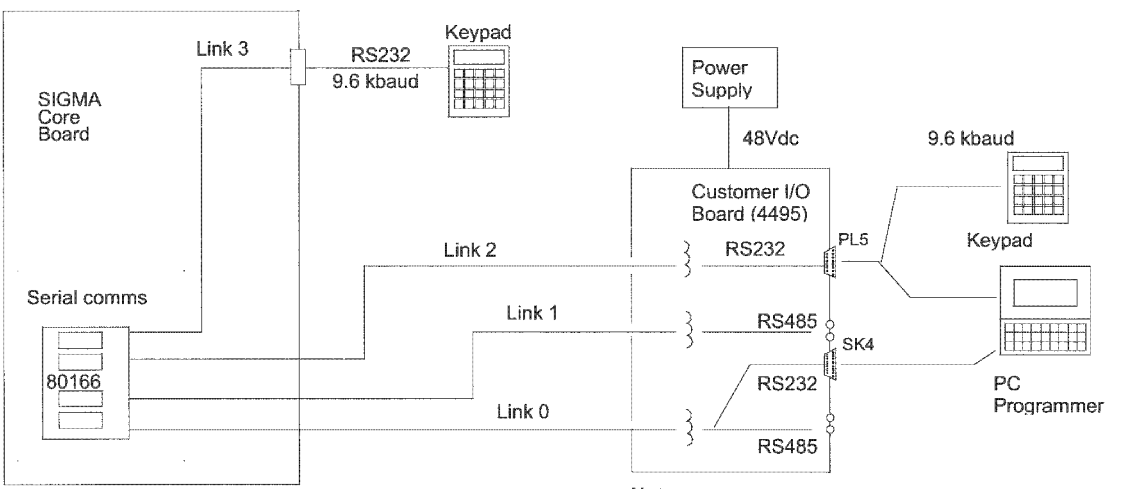
Link 2 can also be used as a general purpose communication port. It is limited to point to point links, with a maximum baud rate of 38.4k.

Links 1, 2 and 3 are configured using the CONFIG (T33) special function.

Link 3 can only be used for the keypad.

Note:
Further links may be provided using the HDLC and/or FIP enhancement cards. These links are separately documented in the Product Data for the associated SIGMA Application module (Module 53 for HDLC, Module 70 for FIP).

Figure 1-4 Serial Link Arrangements



Notes
(1) Customer I/O circuits shown for the 4495 Customer I/O board. RS232 connections via 9 way 'D' type connector
(2) The 4451 Customer I/O boards need an RS485-RS232 convertor to connector the PC to the Customer I/O board link 0

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1.6.2 Serial Link 0

Features

Point to point or multidrop link providing:

- Fully isolated RS485 interface
- ESP protocol or MODBUS for communications and programming
- Baud rates set by coding switches on the Customer I/O Board: 2400, 4800, 9600, 19.2k, 38.4k, 76.8k
- Tributary address 1-14 available (set by Customer I/O coding switch). Address 0 is not recommended for programming use

Interface

- ESP Table exchange - J/K tables. Max of 100 (J0-J100;K0-K100) See section 1.6.6 for details on the operation of an ESP link
- MODBUS RTU or ASCII. See section 1.6.7 for further details

Configuration

Since link 0 must be available as the default programming port a certain number of the configuration parameters are preset. The baud rate and tributary address are set by a coding switch on the Customer I/O Board.

There are two modes of configuration:

a) **New Firmware Database**

A new firmware database is required when a board is powered up for the first time, or has been powered up after the batteries have been removed to clear the contents of the battery maintained RAM.

Under these conditions Link 0 has the following default configuration:

- ESP tributary
- Baud rate defined by SW1 (see Table 1-1)
- Tributary address defined by SW1 (see below)

Table 1-1 Boot System Baud Rate Selection

SW1 2	3	4	Baud rate
off	off	off	38400
off	off	on	9600
off	on	off	9600
off	on	on	9600
on	off	off	9600
on	off	on	19200
on	on	off	38400
on	on	on	9600

Baud rate

Set by A0.12-A0.14 (DIL switches SW1 positions 2, 3, 4 on Customer I/O Board) as shown in Table 1-1.

Tributary address

Set by A0.8 - A0.11 (DIL switch SW2, positions 5, 6, 7, 8 on Customer I/O Board) as shown in Table 1-2.

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b) System loaded.

Once the firmware database has been loaded, Link 0 can be used in one of two ways:

i) Configuration determined by defaults and SW1

Set SW1/1 = 0

Link 0 defaults to an ESP tributary, with the baud rate as given in the table below, and the tributary number determined in the same way as for a new firmware database.

Baud rate

Set by A0.12-A0.14 (DIL switches SW1 positions 2, 3, 4 on Customer I/O Board) as shown in the table below.

Table 1-2 Tributary Number Selection

	SW1			
Addr.	**5**	**6**	**7**	**8**
0	off	off	off	off
1	off	off	off	on
2	off	off	on	off
3	off	off	on	on
4	off	on	off	off
5	off	on	off	on
6	off	on	on	off
7	off	on	on	on
8	on	off	off	off
9	on	off	off	on
10	on	off	on	off
11	on	off	on	on
12	on	on	off	off
13	on	on	off	on
14	on	on	on	off

ii) Configuration via CONFIG special function

Set SW1/1 = 1

The configuration of the link defaults to an ESP tributary, with baud rate as given in the table below, and tributary determined in the same way as for a 'new system'. However, the link can be reconfigured using the 'CONFIG' special function.

If SW1/2 to /4 are changed subsequent to SW1/1=1, the configuration will revert to the switch settings, i.e. the last setting takes precedence

Table 1-3 Firmware Baud Rate Selection

SW1			Baud
2	**3**	**4**	**rate**
off	off	off	9600
off	off	on	600
off	on	off	2400
off	on	on	4800
on	off	off	9600
on	off	on	19200
on	on	off	38400
on	on	on	76800

Warning: It is possible to 'lock out' the user by (for example) configuring link 0 as an ESP master. This would mean it could no longer be used for programming. For this reason take care to ensure that at least one link 0-3 is available for programming.

Fault diagnostics

Serial link statistics recorded in table F50-F59. See section 1.6.8 for details.

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Connections
See the Customer I/O Board Product Data for further information.

1.6.3 Serial Link 1

Features
Point to point or multidrop link providing:
- fully isolated RS485 interface
- ESP protocol and MODBUS RTU or ASCII for communications
- Baud rates: 300, 1200, 2400, 4800, 9600, 19.2k, 38.4k, 76.8k
- Can be configured as communications port (table exchange or programming)
- Control port with up to 4 tributaries or tributary port
- When configured as a programming tributary, the port can have addresses 1-14

Interface
- ESP Table exchange - J/K tables. Max of 100
  See section 1.6.6 for further details on the operation of an ESP port
- MODBUS RTU or ASCII. See section 1.6.7 for details

Configuration
Configuration via the CONFIG T33 special function:
- Link address (control or tributary 1 - 4)
- Number of tributaries on link (if configured as control port)
- Baud rate
- Port type (Communication/programming or printer port)
- Parity and data bits (MODBUS only)

Fault diagnostics
Serial link statistics recorded in table F60 to F99. See section 1.6.8 for details.

Connections
See Customer I/O Board Product Data for connections.

1.6.4 Serial Link 2

Features
Single point to point link providing:
- Full RS232C interface (isolated)
- Programmable baud rates up to 38.4k baud using CONFIG function T33
- baud rate and protocol configurable but new system defaults to 9600 baud ESP tributary 0
- Tributary address range 1-14

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Configuration
On power up the link defaults to trib. 0, 9600 baud. Other configurations can be selected using the 'CONFIG' special function. This sets the following:
- Baud rate
- Port type (ESP, MODBUS RTU or ASCII)
- Tributary address
- Parity and data bits (MODBUS only)

Fault diagnostics
Serial link statistics recorded in table F100 to F109: See section 1.6.8.

Connection
9 way header plug on Customer I/O Board provides fully isolated RS232 signal. (PL5)

Warning
Although baud rates of up to 38.4k can be used it is not advisable to use the maximum baud rate on more than two links. This is because the resultant loading on the I/O processing can affect the performance of other tasks handled by the I/O Processor (such as BASIC I/O).

1.6.5 Serial Link 3

Features
Single point to point link providing:
- Full RS232C interface **non isolated**
- 9600 baud, ESP protocol

Interface
Used for the keypad and display. Section 4.1 gives details of the requirements for the keypad.

Configuration
On power up Link 3 defaults to trib. 0, 9600 baud. Other configurations can be selected by use of the CONFIG special function (T33).

Fault diagnostics
Serial link statistics recorded in table F110 to F119: See section 1.6.8.

Connection
9 way header plug on front panel provides non isolated RS232 signal. Because of this, it is NOT recommended that any peripherals other than the keypad are plugged into link 3.

In particular, this port must not be used as a programming port, because it is not isolated.

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1.6.6 Using ESP J/K Table Exchange

A block of 100 J/K data tables is allocated when the link is a tributary, or 100 J/K tables per tributary when the link acts as a master talking to up to 4 tributaries (link 1 only). The control of the link is via I tables, and statistics are stored in F tables. The allocation is as follows:

Table 1-4 Serial Link Tables

Link no	Trib.	J/K tables	I tables	F tables	Link Activity Table	NOTES
0		J0-J99	rx = I0 tx = I1	F50-F59	F37-F39	
1	1	J100-J199	rx = I2 tx = I3	F60-F69	F40-F42	
	2	J200-J299	rx = I4 tx = I5	F70-F79		Note 1
	3	J300-J399	rx = I6 tx = I7	F80-F89		Note 1
	4	J400-J499	rx = I8 tx = I9	F90-F99		Note 1
2		J500-J599	rx = I10 tx = I11	F100-F109	F43-F45	
3		-	-	F110-F119	F46-F48	Note 2

Notes:

1. **Link 1** operation

   The tables allocated for tributaries 2 to 4 are only used if link 1 is configured as a master talking to up to 4 tributaries.

   The master exchanges data with tributary 0 first, then subsequent tributaries up to the number of partners defined.

   Note that there is no means to switch out a failed tributary. If a tributary stops communicating then the master will wait until the link times out before moving on to the next tributary.

2. Link 3 does not implement table exchange.

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Receiving data:
When an ESP table exchange message is received the 'J' tables are updated before the start of the next user scan. Any data in the J table is overwritten by the new data. The 'receive' I table is set to the length of the received data.

Note:
SIGMA data tables locations are 32 bits in size. Information in an ESP table exchange message is 16 bits in size. The incoming data is sign extended to fit into a 32 bit integer word.

Transmitting data:
Data is transferred from the K tables into the transmit buffer at the end of a scan. The amount of data to transfer is defined by the transmit length I table. Any data already in the transmit buffer is overwritten, although data table integrity is maintained (it is not possible to have a partly updated table).

If the data to transmit is greater than 16 bits then it will be truncated. The number range that can be transmitted up the link is therefore +/- 32767. If a full 32 bit number needs transmitting then the SWAPE special function should be used to transpose the upper and lower 16 bits and the high order 16 bits transmitted in the next data table.

User Program halted
The serial links will continue to operate if the user program is halted, although the outgoing data will not be refreshed and input data will not be read.

1.6.7 Using MODBUS

General
The MODBUS protocol is designed for a PLC (Programmable Logic Controller) where there are separately defined data areas for:

- Digital inputs
- Digital outputs
- Input variables
- Output variables

This is different from SIGMA, which mixes digital and analogue variables in the same area. In addition, the MODBUS spec was written for PLCs, which were not designed for analogue control. The naming of the data areas in such a PLC reflects this. These names are:

Logic coils:	These are used to control discrete outputs from the controller
Input status bits:	Discrete inputs to the controller
Holding register:	Store numerical values of timers and counters
Input register:	Referencing variables. The MODBUS spec says that these 'cannot be altered'

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Functions

Functions are provided for reading all of these, and for 'forcing' coils and 'pre-setting' holding registers, as given below:

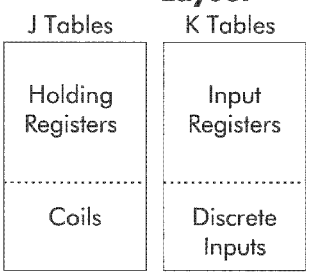
01	Read coil status	Obtain current status of a number of 'J' table bits
02	Read input status	Obtain current status of a group of 'K' table bits
03	Read holding registers	Obtain value held in a number of 'J' table words
04	Read input registers	Obtain value held in a number of 'K' table words
05	Force single coil	Set 'J' table bit ON or OFF
06	Preset single register	Set 'J' table word
07	Loopback diagnostic test	
015	Force multiple coils	Set number of bits in 'J' table
016	Force multiple registers	Set number of words in 'J' table

Addressing

The following address mapping for words and bits is as follows (see also Figure 1-5):

Words: Mapped to offset 0 - 83
Bits: Mapped to 84.00 to 99.15

Figure 1-5 Modbus J/K Layout



The normal link address mapping applies, as follows:

Link	J/K table
0	0-99
1	100-199
2	500-599

1.6.8 Serial Link Fault Diagnostics

See Table 1-4 for the serial link F table allocation.

The meaning of the statistics is as follows:

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Table 1-5 Serial Link Statistics

Table	Statistic
0	Attempts- Number of messages received (included those with errors). Master is requests + errors. Slave is received + messages
1	Requests* - Number of messages replied to
2	CRC - Number of corruption's of the data
3	Hardware errors - fault flagged by the serial link hardware (overrun, framing or message lost)
4	data error - message too long or incorrect data stuffing
5	time-out* - No reply from tributary
6	Terminator error* - Received message has an incorrect terminator
7	NAK error# - Other end has not understood the message
8	Link lost - Master: Flag set if the tributary has not responded, or there is a hardware failure Trib.: Flag set if there is a hardware failure
9	Not used

* Not updated if the link is configured as a tributary.
# Not updated if ESP tributary.
NAK = Negative AcKnowledgement.

1.6.9 ESP Programming Messages

Any of the 4 links can receive programming messages. These messages provide the following functions:

- Read and write data tables
  ESP messages are provided to read and write the SIGMA 32 bit tables.

- Control the controller
  The controller user program can be HALTED, RUN and SINGLE STEPped. TEST and NORMAL mode can be selected. The CLEAR STORE command completely clears the system, including the firmware, and is only used by the programming tools when a new system is to be downloaded.

- Get information
  The controller can be interrogated for information about its identity, the facilities it provides, its status and the size of its memory.

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- Read and write SIGMA addresses
  Memory reads and writes can be performed on the SIGMA RAM areas. This is used for downloading code and data.

- Get history information

A locking mechanism is provided to prevent more than one programming source updating the controller at any one time. Once a programming source has control, it prevents the other sources from making changes until

1. The programming source has not made a change for more than 1 minute
2. The programming source is removed
3. The user program is HALTED and then RUN

When a programming source sets the lock on a message is displayed "Link n programming." This is set on until the lock is released.

If two programming sources are connected and one tries to update the controller when it is locked out, then a message is displayed "Link n cannot make changes." The message is cleared after 5 seconds.

Actions that set the locking mechanism are:
- Halting the drive
- Downloading a program

1.6.10 Connection Details

See Customer I/O Board product data.

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1.7 ENHANCEMENT CARDS

Up to 4 enhancement cards can be connected to the core PCB. The enhancement boards provide a direct connection to the control micro bus, and can be used to provide various functions, such as:

- Specialist serial links (i.e. HDLC)
- FIP network

The enhancement card user interface is similar to a SIGMA Application module i.e. data is read and written via a block of L tables.

1.7.1 Connections

The boards are connected using a DIN41612 96 way connector.

The existence of an enhancement card is indicated by the following:

- The entries for the OIS of the board in the E table (see section 1.8.1)
- The appropriate bit set in E30.5-E30.8 (see Table 1-6)

Table 1-6 Enhancement Card Data Tables

Location	Config.	Present
1	P26	E30.5
2	P27	E30.6
3	P28	E30.7
4	P29	E30.8

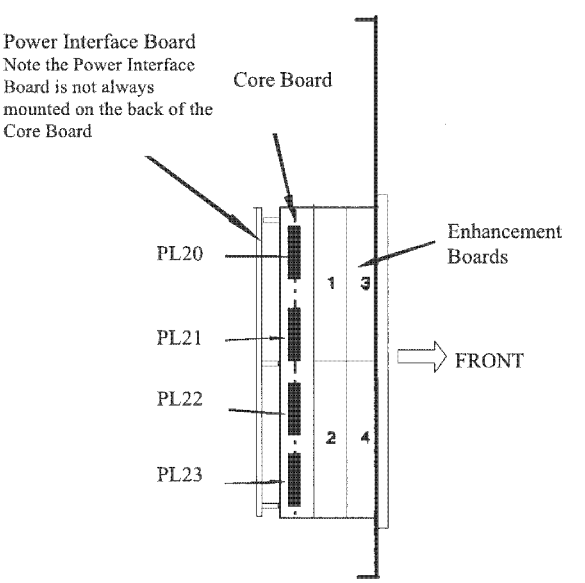
The locations of the boards is as given in Figure 1-6.

1.7.2 Configuration

The interface to the card (and in some cases the operating code) is provided by SIGMA application modules. The application module required for a particular card is defined by entering the module number into the P table appropriate to the card slot position (see Figure 1-6 and Table 1-6). If no module number is entered and a card is fitted in a particular location then the HDLC module (module 53) is assumed.

Note:
The configuration number must be entered into the links program. The configuration is only read on power up (NOT on Halt to Run).

Figure 1-6 SIGMA Arrangement; Left Hand Side View



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IP7015038

1.8 MISCELLANEOUS FACILITIES

1.8.1 Board OIS Data

All boards have a serial EEPROM fitted. This EEPROM contains the following information:

	Description	Format	Example
0	OIS reference	8 BCD digits	'10024001' for GDS1002-4001
1	Board Ref. & comb. no	8 BCD digits	'44510010' for 20X 4451/10
2	ENU State & Boot issue	4 BCD + 2 ASCII	'0102'"BA" for ENU 1/2/B, EEPROM issue A
3	Modification author	4 ASCII chars	"MJLC"
4	Modification date	8 BCD digits	'19930929' for 29th Sept 1993
5	Serial number	8 BCD digits	'00000027' for serial no 27

Remainder of EEPROM contains additional board specific data (e.g., Operational Amplifier gain and offset information).

The product reference and OIS reference together identifies the board and its casing. It does not refer to the firmware database loaded in via the serial link, or any additional cards fitted to the board (e.g. in the case of the core board, it does not refer to the enhancement cards).

The board reference, combination number, ENU status and EEPROM issue defines the hardware build of the board.

Data items 0 to 4 can also be accessed via the keypad, or via the 'E' table.

DATA	Core Board	Cust. I/O	PIB 1	PIB 2	PIB 3	EH1	EH2	EH3	EH4
Product Ref. & OIS	E31	E63	E95	E127	E159	E191	E223	E255	E287
Board Ref. & comb. no	E32	E64	E96	E128	E160	E192	E224	E256	E288
ECN & Boot EEPROM no	E33	E65	E97	E129	E161	E193	E225	E257	E289
Mod. Author	E34	E66	E98	E130	E162	E194	E224	E258	E290
Mod. Date	E35	E67	E99	E131	E163	E195	E225	E259	E291
Serial Number	E36	E68	E100	E132	E164	E196	E226	E260	
Additional data	E36-E62	E68-E94	E101 - E126	E133 - E158	E165 - E190	E197-E222	E227-E254	E261-E286	E292 - E318

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IP7015039

E30 contains information on the devices actually present, as follows:

Bit no	Board Description	Hex Value
Bit 0:	Core Board	1
Bit 1:	Customer I/O Board	2
Bit 2:	Power Interface Board 1	4
Bit 3:	PIB 2	8
Bit 4:	PIB 3	10
Bit 5:	Enhancement Card 1	20
Bit 6:	Enhancement Card 2	40
Bit 7:	Enhancement Card 3	80
Bit 8:	Enhancement Card 4	100

1.8.2 OIS Protection

If the data in the serial EEPROM is valid at power up then the data is copied into an internal table in the 960 data area, otherwise the data area is set to 0.

Once all serial EEPROMs are read, then the OIS number identification is checked against the OIS number for the appropriate board as defined by the user program. If the user program OIS is zero, or the numbers match, then a bit is set in an internal OIS_OK variable (V231), otherwise the bit is set off.

The bits are as given for E30.

The watchdog is tripped (trip 34) if there are any zeroed bits in the OIS_OK table. This trip cannot be masked by the normal route (P3) but can be prevented by setting the relevant user program OIS definition to zero. Note, however, that the purpose of defining OIS numbers is to ensure that the software is correct for the hardware it is being run on. This is particularly important with regard to the Power Interface Boards (PIB), where damage could be caused to the PIB by the wrong program.

1.8.3 Calendar Clock

A chip is fitted to the core board to provide clock and calendar facilities. The clock continues running as long as the battery supply is healthy. The clock is not synchronised to the system's real time clock.

Clock time can be read and changed via the following data tables.

E1 = sec
E2 = min
E3 = hour
E4 = day
E5 = month
E6 = year

If the batteries are removed and the SIGMA powered off then the contents of the calendar clock are cleared and the time will be undefined on power up.

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Provided the battery supply is healthy the SIGMA clock will operate correctly for the year 1999 to 2000 transition, whether in a powered up or powered down state.

1.8.4 Miscellaneous Timing Functions

Two timing flags are made available to the user. These are:

E0.0: 100 ms marker
E0.1: 1 s marker

These flags are set on for one scan. The second flag is synchronised to the 0.1 second flag, but not to the seconds count in the calendar clock.

1.9 BATTERY

The backup battery supply is used to maintain the user program in RAM when the normal supplies are switched off.

Battery type LR14
Number 3 (in series)

These batteries are fitted to the inside of the SIGMA Core Moulding, behind the keypad or keypad dummy panel.

Replacement Procedure:

It is recommended that the batteries are replaced every 12 months or whenever the WARNING lamp on the keypad is on.

1 Leave normal supplies on (to prevent loss of information)
2 STOP the drive
3 Remove keypad if fitted
4 Remove old batteries
5 Fit new batteries

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IP7015042

2. FIRMWARE DATABASE

2.1 INTRODUCTION

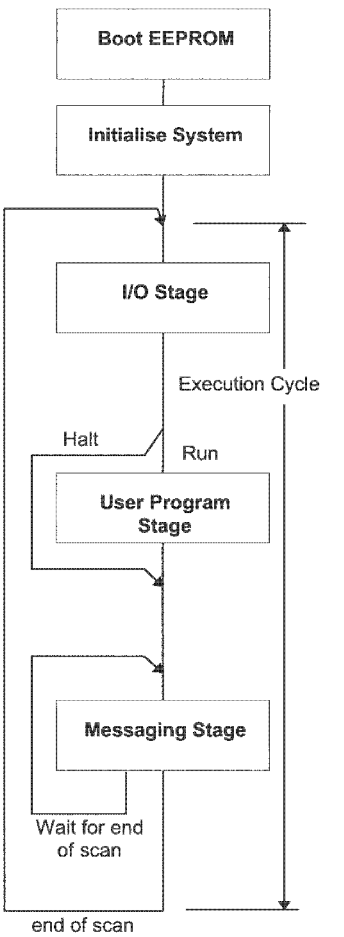
The firmware database (also sometimes known as the system software) provides the background resources to the application programmer to enable the I/O to be serviced, the integrity of the microprocessor system to be checked and executes the application program.

The firmware is held in RAM. This enables enhancements and 'bug corrections' to be made to the system without having to change EEPROMS.

The firmware reference (of the form *GDS1106-xxxx*) can be obtained by any of the following means:

- CSP Monitor
  Firmware reference displayed on top line of monitor
- Keypad - "Display Issue Information"
- Firmware Database disk supplied
  On label

Figure 2-1 Firmware Overview



2.2 EXECUTION SEQUENCE

Refer to Figure 2-1 - Firmware Overview for an illustration of the following sections.

2.2.1 BOOT EEPROM

Software in the BOOT UP EPROM is executed either on a power up or when new firmware has been loaded.

The BOOT UP code is used to start up the RAM based code. If there is no code in RAM, the boot code copies code from FLASH or the serial link into RAM.

Note that the error messages that may be generated are listed in section 4.3.3.

2.2.2 Initialise System

MEMORY CHECKS
The various memory components are checked. If there is a failure, execution will continue but the watchdog does not pick up and a fault message is displayed.

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I/O PROCESSOR
The I/O processor is started. This enables information to be passed out over the serial link, and information to be obtained about the update status of the boards connected to the system. The I/O Processor performs the following checks:

- Dual port RAM check
- EEPROM CRC
- RAM Checks
- Supply checks
- Basic I/O highway checks
- Set up serial link systems
- Set up and read serial EEPROM data

INITIALISE DATA TABLES
The data tables are cleared and initialised (see table in section 4.5.12).

FAST TASK
The fast task, which drives the power convertor, is started.

DIGITAL INPUTS
The Digital inputs are read and drive ID information stored.

STATUS INITIALISATION
The status flags are set. If the drive was running when it was last powered off, a 'request to run' is set, otherwise it is held halted.

The system is now ready to perform its first 'Execution cycle'.

2.2.3 Execution Cycle

An 'execution cycle' is similar but not the same as a user scan. The user program is only executed if the controller status is 'running'. An execution cycle always occurs, whatever the status of the controller.

The following actions are performed for each execution cycle:

STATUS
The controller status is determined.

Changing from 'halted' to 'running' (of the user program) depends on the following:

- The programming permissive (A32.7) being LOW
- Drive ID correct
- Watchdog running

The controller status is tripped immediately a watchdog trip occurs.

If the user program is running, it can only be halted by the user if the programming permissive is LOW (A32.7 off).

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A transition from HALT to RUN clears the data tables (as defined in the table in section 4.5.12).

For more details on HALT-RUN and RUN-HALT transitions, see section 2.3.

OUTPUTS
The outputs are written as long as the controller is in the 'RUN, NORMAL' status, otherwise all outputs are set to 0.

- The B table values are passed to the I/O processor for writing to the appropriate Basic I/O
- The D tables are written to the analogue outputs

INPUTS
The inputs are read.

- The fast digital inputs are debounced by 1 scan and transferred to A32 and A33
- The Basic I/O inputs are read from the I/O processor and transferred to the A tables
- The analogue input values read by the fast task are transferred to the C tables
- The supply values read by the I/O processor are transferred to the C tables

SUPPLY CHECKS
The supply checks are performed. If there is a supply fault for more than 100ms then the watchdog is tripped and a fault message is displayed. The supply ranges are given in section 4.5.14.

HOUSEKEEPING
Various housekeeping functions are performed (such as maintaining the 0.1ms and 1 second flags (E0.0 and E0.1)).

USER PROGRAM
If the controller status is 'RUNNING' then the user program is called.

The controller now executes the messaging stage.

2.2.4 Messaging Stage

This is a background task that is serviced at least once every execution cycle. The loop is serviced until the total execution time from the start of the execution cycle to the present time exceeds the time set in P1. The following functions are performed at this stage.

SERVICE SERIAL LINKS
The I/O processor is responsible for the handling of the communications protocol on links 0-3. The control processor is responsible for transferring the data to and from J and K tables, or responding to control or edit messages.

TIMING FUNCTIONS
The clock, calendar and time-out functions are updated at this point.

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SELF TESTS

The self tests are performed at this point. To minimise the effect of self tests on the execution cycle only a section of the memory tests is performed each scan. The total memory can take several minutes to check.

2.2.5 End of Execution Cycle

At the end of the execution cycle the scan time in E7 is updated. The watchdog is reset if the watchdog has not yet been initialised and there are no watchdog faults.

2.2.6 Execution Scan Time

The scan time of the Slow Task can be set by the user through P1 in data tables. This has a resolution of 1 μsec. A maximum scan time of 65ms can be set. The system clock is used to time out the scan time. If the scan time exceeds P1 then the system will free run.

Due to other activities of the processor (such as the fast task and serial link information handler) the scan time of the control task varies about the set value. The average scan will be maintained at the level set by P1, provided that the system is not free running.

The scan time of the fast task is not user programmable.

The scan time for the previous scan is recorded in E7. E10 is incremented for each scan where the user program free runs. (This is defined as when the background loop only has enough time to execute once in a user scan).

At the end of a scan, calculates
User Scan Time (P1 value) - Current Time.

If there is time left to do a background loop again, it will. (i.e. Current time # - Time now *)

If time not left, it goes back to start of Execution Cycle.

If Execution Time is greater than P1, it will compensate for this on the next scan to make the average Execution Scan Time = P1.

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2.3 HALT/RUN STATUS

The user program can only be halted or run from CSP or OVERVIEW. The keypad cannot be used to control this function. SIGMA can be configured to automatically run the user program on power up by setting P9.0 =1 in the links program. The conditions below apply.

2.3.1 RUN Conditions

The user program only performs a HALT to RUN transition if the following is true:

The PROGRAMMING PERMISSIVE is LOW
The programming permissive is digital input A32.7. If this is high and there is a 'request to run' then a warning message is issued. The fault can only be cleared and the controller run by setting the Drive permissive low.

Typically the A32.7 input is connected to the 'convertor supply on' logic, and ensures that changes cannot be made unless the supplies are off.

The program only halts with A32.7 high if the watchdog is tripped.

The Drive ID is correct
The 'Drive ID' facility is designed to ensure that the correct user program is loaded into the correct drive. It cross checks a value in the user program with a value read from the hardware in the cubicle.

The Drive ID is read from SW2 on the Customer I/O Board during power up (digital input A0.0 - A0.7). If P8 is set then this value is checked against the bottom 8 bits of P0. If there is a discrepancy then the drive will not run, and a warning message is displayed.

This fault can only be cleared by:
- Switching off the drive and changing SW1 to match P0
- Changing the value of P0 in the user program, recompiling and reloading the user program
- Setting P8 off in the user program, recompiling and downloading

A copy of the drive ID read from SW2 is held in E21.

The watchdog is correct
The controller can only run if the watchdog is healthy.

Note: The watchdog is held in an 'initialising' state for the first scan of the execution cycle. This ensures that all the self checks are performed before the watchdog is set running. The consequence of this is that the controller is always in a 'halted' state for the first scan of the execution cycle.

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2.3.2 Power Up Conditions

The status of the drive is remembered through power off. i.e. If the program is running when the power is removed then the system will come up in the 'running' state, provided that the checks given above are correct. If the drive is halted before power down (for example, because of a watchdog trip), then the system will power up in a halted state.

If P9.0 is set on the status will be set to run irrespective of the state before power down (provided that the halt-run checks given above are successful). Applies to current and future firmware databases.

2.3.3 HALT Conditions

The user program can only be halted by the user if the 'Pulse enable' input (A32.7) is low. A watchdog trip will always halt the user program automatically.

2.3.4 Monitoring

The flag E0.6 is applied for one scan following a halt-run transition.
E11.0 is set on for the program running, set off for halted.

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2.4 OTHER MODES

2.4.1 Test/Normal Status

A facility is provided to be able to change the output values without affecting the plant. This is provided by the test facility. In this mode all outputs are written to zero and are not affected by the values in the output data tables.

Inputs affected	Outputs affected
All A tables	All B tables
	D tables

Flag E11.1 is set on in test mode.

The controller must be halted to switch between modes.

2.4.2 Commissioning Mode

Commissioning edits can be made using the links editor. These program changes are only applicable when commissioning mode is selected. They are removed when normal mode is selected. The method of making commissioning mode changes is detailed in the CSP manual.

The user program needs recompiling and downloading whenever the mode is changed.

A flag E11.2 is set when the program is in commissioning mode.

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2.5 SUPPLY CHECKS

2.5.1 Analogue Supplies

If the supplies are out of range for >100ms, then the watchdog trip 16 occurs. See section 4.5.14 for details of ranges.

2.5.2 Battery Monitor

The battery supply is also checked by a battery supply monitor, which sets A35.0 = 0 for battery low. The monitor is checked at power up and subsequently every 5 minutes. (The battery check applies a load to the battery circuit, and therefore is used sparingly to avoid significantly affecting battery life).

2.5.3 Early Power Fail (A35.2)

The SIGMA power supply provides an early power fail warning. Given that the power supply hold up time is a minimum of 20ms, the signal will occur 20ms before the loss of supplies.

The early power fail signal is read into A35.2, and is 1 for healthy, 0 for fail.

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2.6 FLASH PROGRAMMING

2.6.1 Summary

If **'Program FLASH'** is selected then the contents of RAM will be transferred to FLASH if there is a difference between RAM and FLASH images. This transfer occurs when **run** is requested, provided there is no watchdog failure and the hardware permissive **(A32.7)** is off.

If **run and program** is selected the SIGMA is run and FLASH programmed in parallel. THIS IS NOT RECOMMENDED, since scan times can be quite large. See the discussion in section 2.6.8.

If **pack sections** is selected then the most efficient use of FLASH space is made, at the expense of having to reprogram the entire FLASH from RAM on a partial download.

Setting **flash error trip** on will trip the watchdog if there is an error.

Note that setting **program FLASH** off clears the FLASH contents if there is a program held in FLASH. This ensures that old programs are not retained and cannot overwrite new programs.

Use of the **clear store** command will also invalidate the FLASH system. As usual, the SIGMA must be power cycled following a clear store/download cycle in order to reset the watchdog. If batteries are not fitted IT IS IMPORTANT that this action is only performed once the FLASH has been programmed by 'running' the user program and waiting for programming to finish. (See section 2.6.9 on loss of power when programming FLASH).

Monitoring flags are provided to check the operation of flash - see section 2.6.5.

2.6.2 Restoring Program From FLASH

If batteries are fitted then the contents of FLASH is ignored - if there is a valid system in RAM then this will be executed.

If batteries are not fitted then the contents of FLASH will be transferred to RAM provided that the contents represent a valid program. The LED on the SIGMA core board will display a 7 whilst this is occurring.

It is possible to disable the transfer of code from FLASH to RAM by setting the switches on SW2 on the Customer I/O Board all 'ON'. This facility might be required if there was a problem with the code held in FLASH. New firmware can then be downloaded via the serial link.

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2.6.3 Issues To Note With Batteries Not Fitted

Lack of battery support has the following consequences

- R and W tables are no longer maintained through power loss
- The 'run' status is no longer maintained through power loss. The system will power up in a halted state unless the **run on power up (P9.0)** flag is set.
- Certain variables (such as encoder position in module 20) are not remembered through power loss

2.6.4 Parameters

P9.5	Program Flash	Set on to back RAM up to FLASH
P9.4	Run and program	FLASH backup and user program run occur in parallel
P9.6	FLASH error trip	Trip watchdog (error code 18) if FLASH programming fault
P9.7	Pack section	RAM image packed contiguously into FLASH
P18	FLASH block size	Max. number of bytes transferred to and from RAM to FLASH each scan. Default = 10,000 bytes

Note: All parameters have a default of 0 unless otherwise stated.

2.6.5 Monitoring

E11.4	Writing to FLASH	Set high when flash being written to
E11.5	Flash error	Set high if FLASH programming error; goes low on next attempt to program FLASH
E386	% FLASH used	Amount of available FLASH used (excluding the boot code area) in %
E387	FLASH bytes free	Number of bytes remaining

2.6.6 Control

E388.0	Program FLASH	Transfer RAM to FLASH if difference
E388.1	Clear FLASH	Clear FLASH contents

2.6.7 Errors

If **P9.6** set, trip watchdog.

F1 = 18 (Flash error)
F2 = Error code
F3 = Further data

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2.6.8 Program and Run

The **program and run** flag is provided so that users have the choice of 'running' the user program as soon as a run request is issued (either from the programming port or as a result of the 'run on power up' flag **P9.0** being set). The default is for the run request to be deferred until the FLASH has been programmed, which can be up to 30 seconds after the run request is issued.

The penalty is that the programming of FLASH can severely affect the scan time, to the point of making drive control unusable. A number of bytes is programmed per scan, as set by **P18**. This defaults to 10000, which can give scan times whilst writing to FLASH of 60ms or more (at which point the speed feedback calculation will fail). Reducing the amount of bytes programmed also reduces the scan time loading, at the expense of a longer programming time.

2.6.9 Loss of Power When Programming Flash

If power is removed whilst FLASH programming is in progress then the entire contents of FLASH will be invalid and will require reprogramming. If no batteries are fitted then a full download of the firmware and user program will be required. The reason for this is that the validity of FLASH is determined by performing a CRC. This CRC is cleared at the start of programming and only recalculated and written to FLASH at the end of programming.

If batteries are fitted then the boot system will execute the system in RAM without checking the FLASH system.

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2.7 WATCHDOG

A watchdog circuit is provided to protect against a fault in the microcontroller going undetected. This is because the normal means of detection and information is performed by the controller itself. If this goes faulty, then it could either fail to detect the fault or be unable to inform the user that a fault has occurred.

The watchdog is not intended as the prime means of personnel protection or as prime protection against plant damage. The reason for this is that a fault in the code (e.g. code corruption) may not be detected for up to 10 seconds after the fault has occurred. See **Health and Safety**, page ii.

2.7.1 Watchdog OK LED

A Watchdog OK LED is provided on the Customer I/O Board. This LED is on for the healthy state.

2.7.2 Watchdog Circuit

The watchdog circuit requires a pulse from the control micro every 50ms ±10ms. Failure to do so within the specified window results in the output of the circuit tripping the watchdog relay on the customer I/O board. A hardware latch prevents the watchdog being picked up again without the board being powered off.

Tripping the watchdog relay also applies a hard wired pulse inhibit to the pulses.

The integrity of the watchdog circuit on the SIGMA Core Board is also checked by tripping it every 10 seconds, checking that the relay volts start to fall, then resetting it before the contact can drop out.

A check is made for a 'stuck contact' at power up by monitoring one of the watchdog relay contacts on the core board.

Input A35.1 monitors the state of the watchdog contact on the SIGMA core board.

A35.1 = 1: Watchdog healthy
A35.1 = 0; Watchdog tripped

2.7.3 Watchdog Start Up Checks

On start up the following items are checked and the watchdog held tripped if a fault detected:

- Microprocessor memory (both control and serial comms)
- Power supplies (±15V, 5V)
- Voltage references (used in A/D, D/A conversion)
- Presence of main boards (Customer I/O, Power Interface Board, - current and future firmware databases)
- Basic I/O driver

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All items can be masked out.

If possible a message is displayed giving the nature of the fault.

LED's are also fitted to the 960 core board which provide:
micro 5V healthy (ON = healthy)

80960ca microprocessor healthy (ON = healthy)

A seven segment display is provided to give up to 8 fault codes for expert diagnostics. Refer to section 4.3.3 for details.

2.7.4 Checks When Running

The following items are checked when running and the watchdog tripped if a fault is detected.

- Microprocessor memory
- Power supplies
- Voltage references
- I/O processor checks
    - Serial link subsystem
    - Serial EEPROM system
    - I/OP memory
    - Basic I/O

2.7.5 Watchdog Error Codes

Watchdog error codes are covered in detail in section 4.4.

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2.8 DOWNLOADING A NEW SYSTEM

The downloading of a new system is described in the CSP Technical Manual, and in the OVERVIEW Technical Manual.

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3. APPLICATION SOFTWARE

3.1 INTRODUCTION

The SIGMA Controller contains a large number of software modules that are linked together to perform two tasks:

- A **Fast Task**, using fast task software modules, dedicated to high bandwidth closed loop controls, for example, a closed loop current control producing mains synchronised thyristor firing. The modules are linked together. Unlike the control task, the fast task variables are not directly linkable except for the linking of references, parameters and monitoring outputs.

- A **Control Task**, using control task software modules, which executes a user defined application program.

The user program is in two parts, the **Ladder** program and the **Links** program. Each has its own editor. The links program is further divided into the header section and the links program proper.

The user program is produced and edited by means of the CSP or OVERVIEW software programs. These PC based programs are fully detailed in the appropriate Technical Manuals. Only CSP is referred to from here on, but comments apply equally to both programming tools.

The CSP can link modules and edit parameters in the control task and edit parameters in the fast task. It can also incorporate ladder programs and monitor values. The keypad cannot link modules, but it can edit parameters and monitor values, keypad edited values are however temporary, and not stored to the user program.

The user program defines the application. This program comprises a sequence of ladder and link statements, which call up and link together a set of software modules. Preset tables are also used to set up the drive configuration.

The combination of the ladder and links user program allows the use of tested and proven module blocks, together with the ability to customise the drive to the application requirements. The ladder allows the use of logic and data manipulation using maths functions, logic functions and special functions.

3.2 SOFTWARE MODULES

The SIGMA Controller contains a large number of software modules which are linked together to perform the fast and control tasks.

The controller contains a predefined set of software modules (e.g. L21, L22, L101 etc.) held in RAM which is called the firmware or system software. The reorder number of the firmware determines which software modules are available. A simplified block diagram of an arrangement for a d.c. drive is shown in Figure 3-1.

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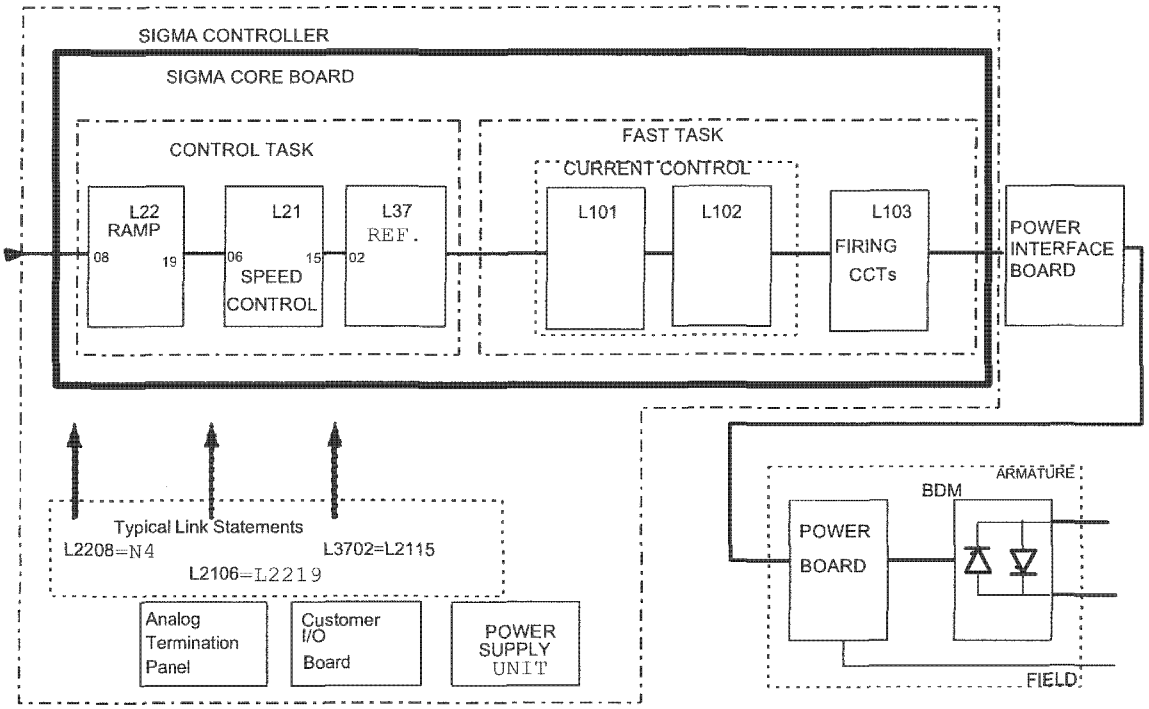
IP7015057

3.3 LINKS PROGRAM

The links program is in two parts, the header and the links program.

Figure 3-1 Simplified Application Block Diagram



3.3.1 Header

An example of a header might be:

↓Line No.
↓ Program
↓ Description

1	STAND F1 MASTER		<- Drive title) Up to 16 characters
2	AA1.0002		<- Drive reference) permitted
3	1105-6004		<- Firmware reference (must be correct)
4	01-05/05/91		<- Issue number & Date (Do not use leading 0 with CSP issue D)
5	FAST TASK	4	<- Fast task type
6	LANGUAGES	: UK	<- See Below
7	SYMBOLS	: YES	<- Allow full symbol table download to drive
8	USERPROG	: NO	<- Keep user program backup in drive
9	CORE OIS	: 0000.0000	<- Core board OIS version
10	CUST OIS	: 0000.0000	<- Customer I/O Board OIS version
11	FIR0 OIS	: 0000.0000	<- Power Interface Board 0 OIS version
12	FIR1 OIS	: 0000.0000	<- Power Interface Board 1 OIS version

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13	FIR2 OIS	: 0000.0000	<- Power Interface Board 2 OIS version
14	ENH0 OIS	: 0000.0000	<- Enhancement Board 0 OIS version
15	ENH1 OIS	: 0000.0000	<- Enhancement Board 1 OIS version
16	ENH2 OIS	: 0000.0000	<- Enhancement Board 2 OIS version
17	ENH3 OIS	: 0000.0000	<- Enhancement Board 3 OIS version

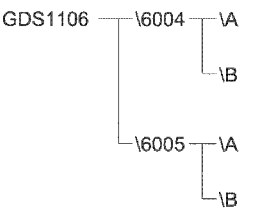
Note, the line number is a documentation guide only.

Lines 1,2,4
The Drive Title, Drive Reference and the Issue Number & Date are ASCII text lines of 16 characters.

Line 3
The firmware reference (maximum 16 characters) is used to select the required firmware database. The database is normally of the format 1106-6004. It is also possible to specify the version of data base (e.g. GDS1106-6004D). The default is the latest version.

Selection of multiple databases depends on the firmware database files **arc** being stored in a defined directory structure as shown in Figure 3-2.

Figure 3-2 Firmware Directory Structure



The root directory is set up in the configuration section of CSP or OVERVIEW.

On entry to the CSP editor each link is checked for validity against the firmware database and an error flagged if a link specified in the program file does not exist in the firmware database.

It is possible to abort the edit session by pressing <CTRL> <F10>.

Line 5
The Fast Task number is normally set to 1.

Line 6
The LANGUAGE statement above specifies the language of the data table comments to be downloaded to the drive. IBM PC standard abbreviations for languages are used. The SIGMA Controller can hold comments in two languages. At present only the English (UK) language is available.

Line 7
This must be set to YES.

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Line 8
If USERPROG option is set to yes then a backup, un-compiled version of both the .GLP (ladder) and .GDM (links) files will be stored in the SIGMA Controller. The UPLOAD facility is not yet implemented. If no is set, the down load time is reduced.

Lines 9 on.. Current and future firmware databases
The number of lines depends upon the hardware fitted. The OIS definitions consist of a four digit OIS number and a four digit Product Reference. They are passed to the drive to check that the correct hardware is attached. See section 1.8.1 for information on the OIS tables.

If the OIS version number is entered as 0000.0000 the OIS number is not checked.

3.3.2 The Links Program

Function
The links program defines the connections to the software modules. It has three functions:

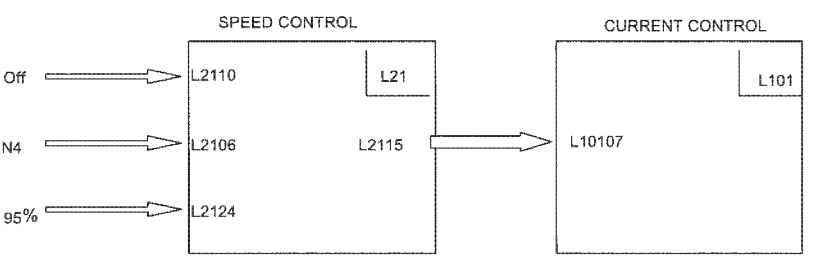
- Linking the data in one location to another
  e.g. L10107=L2115 (equivalent to a wire link)
- Setting the value of a location
  e.g. L2124=95.00 (equivalent to a potentiometer)
- A switch or logic value
  e.g. L2110=0 (equivalent to a switch)

Rules
Only three simple rules apply:

- Input on the left hand side
- Only one input to a location, any number of outputs
- A link statement takes precedence over a ladder rung

Example
The following example illustrates the principles from a small section of the program.

Figure 3-3 Links Example



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The speed reference is obtained from a serial link, table location N4, and is connected to the input of the speed control module L21 at location L2106. The output of the speed control is connected as the current reference to the current control module L101. The current limit is set at 95% and voltage feedback is not selected.

The equivalent links program being:

				Table descriptions, (from firmware)		
L10107	=	L2115	N	CURRENT REF	=	CONTROL OUTPUT
L2106	=	N4		SPEED REF	=	
L2110	=	0	L	SEL. VOLT FEEDBK	=	0
L2124	=	95.00	C	MAX. OUTPUT LIM	=	95.00%

↑
These letters are the link attribute which is associated with the password level, see section 4.5.7

Note, if a value is being linked to a location then the value may be expressed in decimal or hex.

Comments
Comments can be added in the middle of the links program to remind the user what the particular part of the program is about etc. These are added by preceding the comment with a ;.

3.3.3 DEF TABLE Command

Redefines the six attributes of any data table in the links program, i.e. maximum and minimum limits, scaling, default, units and text comments. All six attributes must be set, or a default value will be applied.

e.g. DEF TABLE L7006=10000,-10000,2,0,1,Slave speed ref.

In the above example we are defining the location L7006 to be:

+10000	=	Maximum limit *
-10000	=	Minimum limit *
2	=	Scaling, i.e. divide value by 10^2
0	=	Default value
1	=	Units of displayed value (see Table 3-1 below)
Slave speed ref.	=	Text string (max. 16 characters) in links listing

* Note, limits cannot be written higher than the limits that exist on the module.

If it is only required to change the comment (text string), the user can type, for example:

DEF TABLE L2106=,,,,,New text

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DEF TABLE is normally used at the beginning of the production of a links program, then each time the table is used the required text will be displayed. However if the DEF TABLE is used after the link is made, the required definition will not be applied until F6 is pressed, refer to the CSP Technical Manual.

Table 3-1 DEF TABLE Units

0	=	blank	10	=	/s
1	=	%	11	=	RPM
2	=	PU	12	=	V
3	=	ms	13	=	A
4	=	s	14	=	kW
5	=	%/s	15	=	Nm
6	=	Pk/s	16	=	mm
7	=	PULSE	17	=	ins
8	=	DEG	18	=	mils
9	=	Hz			

3.4 LADDER PROGRAM

3.4.1 General

The ladder program is based on the GEM80 ladder with the addition of certain special functions specific to the SIGMA Controller. The SIGMA user program may be entirely the ladder program, used for example for use as a PLC, but normally has an associated links program. A full description of ladder language can be found in the GEM80 Programming Manual. See description in section 3.4.6 for variations between standard GEM80 functions and their SIGMA implementation.

When used with the links program, the ladder program serves the following functions:

- Configuration of ESP serial links
- Invoking (calling up) of software modules
- Any special logic requirements

3.4.2 Serial Link Configurations

ESP Serial links to the controller are configured in the ladder program using the special function T33. Reference should be made to separate documentation covering this function.

HDLC serial links are configured using the HDLC Module L53, reference should be made to the documentation on L53.

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3.4.3 Invoking Software Modules

The software modules for the control task are invoked (or called up) individually and in order, by the special function S140 (see the example below). By this means, only the control task modules that are required in the user program are executed each scan of the program. Reference should be made to separate documentation covering this function.

```
|  GDMMOD                                                                  DUMP |
+--<SPEC>-------<VALUE>-------------------------------------------------(OUT)-+
|   S140         L2100                                                     G10  |
```

3.4.4 Logic Requirements

When the user program contains a links program, certain limitations/restrictions in the links program may be overcome by the use of ladder program.

A software module can only have one input. This may be overcome by a simple ladder rung such as the example from an application shown below. This application also shows the use of delay functions etc.:

```
|STMTEST          DL01    DL01V          TESTFL1                          LL2215|
+--] [----<INV>---DELAY---VALUE---<INV>-+--]/[----------------------------( )--+
|L4911.0           G32     G33          | M1.2                             G5.4 |
|                                       |                                 ( 158 )
| NOMIM                                 |                                       |
+-] [-----] [---------------------------+                                       |
| G80.0   M1.3                                                                  |
|                           Select slow ramp if no metal in mill (M1.3          |
|                           training  disable) or stimulation.                  |
|                           On loss of stimulation delay switching to normal    |
|                           ramp rate                                           |
|                           Disenabled if test cycle selected                   |
```

Ladder rungs may be added for the checking of serial links, or the moving of data tables. For certain applications the user program may be entirely ladder, the SIGMA Controller acting in effect as a PLC.

3.4.5 Ladder Instructions

The ladder instructions listed in section 3.4.6 are supported. The keyboard template below indicates the keyboard functions.

ADD	SUB	COUNT	DELAY	Shift	SEQR	OR	XOR	INV	Shift	JUMP	-(S)-
SPEC	BLOCK	AND	VALUE		OUT	LINK	JOIN	-][-	Ctrl	-]/[-	-( )-
F1	F2	F3	F4		F5	F6	F7	F8		F9	F10

Special functions, as defined in section 3.4.6, are also supported. In addition, the special function S140 is used to call a control task software module.

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IP7015063

3.4.6 Special Functions

The following special functions are implemented on SIGMA. The major difference between these functions and the standard GEM80 special functions is that SIGMA uses 32 bit data tables, as opposed to the standard GEM80 16 bit data tables. The special functions have been written to use 32 bit data tables.

Function	Ref.	Notes
DBOUNCE	S0	
HISTATE	S3	Detects highest ON bit in bits 0-31
SWAP	S4	Swaps bytes in a 32 bit word
NEGATE	S5	
ABS	S6	
NONZERO	S7	
OUTPUT	S8	
LINCON	S11	Number range is 32 bit integer
SQRT	S12	
LOCATE	S20	Output address is a 'pseudo GEM80 address'
FGEN	S30	
DEDBAND	S31	
LIMIT	S32	Limits up to a 32 bit integer number range
SWAPE	S42	Swaps the upper and lower 16 bits of a 32 bit word
GDMMOD	S140	
EQ	T1	
NE	T2	
GT	T3	
LT	T4	
GE	T5	
LE	T6	
MAX	T7	
MIN	T8	
MULT	T10	
DIV	T11	
FILL	T17	Input address is a pseudo GEM80 address
MOVE	T20	Input address is a pseudo GEM80 address
CONFIG	T33	Configure links 1,2

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The following in-built functions (ladder instructions) are also supported:

Function	Notes
ADD	32 bit integer maths, limit at 32 bit range
SUB	as above
COUNT	Uses bits 0-30; Bit 31 used as last input memory
DELAY	Delay units specified in P5. Minimum is 1 ms; Default is 1ms
SEQR	Sequences bits 0-31
OR	
XOR	
INV	
JUMP	
SPEC	
BLOCK	
AND	
VALUE	
OUT	
LINK	
JOIN	

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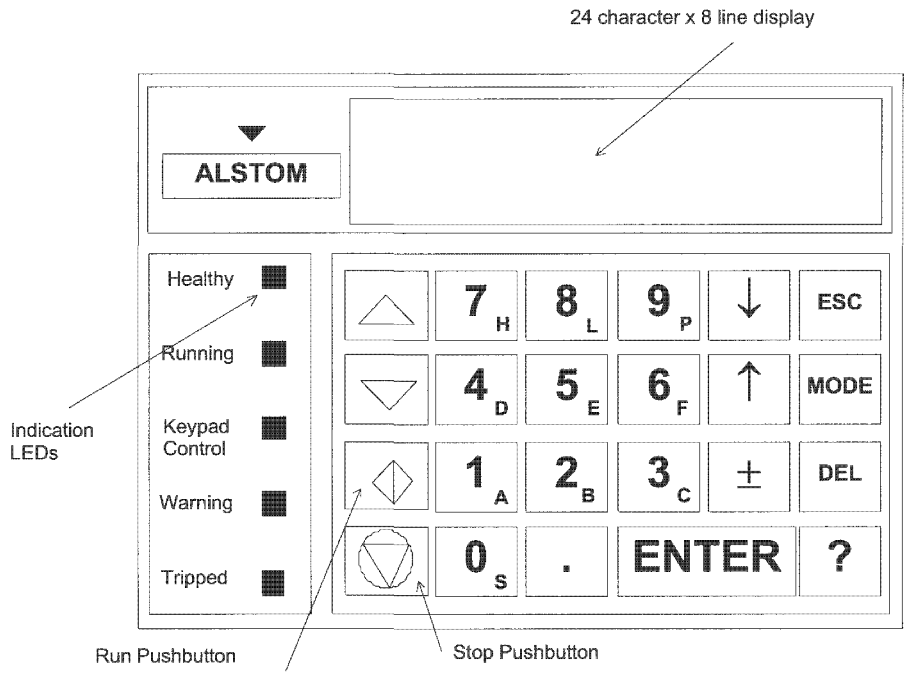
4. USER INFORMATION

4.1 KEYPAD

4.1.1 Keypad Diagram

Figure 5-1 SIGMA Keypad



4.1.2 Introduction

The optional keypad provides control and programming facilities for the SIGMA series of drive controllers. It can either be mounted directly on the front of the drive unit, or it can be mounted remotely giving more convenient access to the SIGMA control and monitoring functions.

The keypad is a small moulded unit with a 'super-twist' liquid crystal display and a membrane keypad containing nineteen programming keys, four drive control keys and 5 LED indicators. A 9-way D-type connector at the rear of the keypad connects directly to the RS232 port or connector on the front panel of a SIGMA unit (link 3), or an extension cable can be used to mount the keypad in a remote location, up to 15m away, on link 2. The general appearance of the unit is shown above. Power for the keypad is derived from the 9-way D-type connector. The keypad is powered up when it is connected to the drive unit.

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The unit can be connected via the local keypad link (link 3) on the front of the SIGMA Controller, or remotely via the Customer I/O Board (link 2). Although there can be more than one item connected capable of changing variables, only one of these items can change variables at any one time. The unit can also be connected to links 0 and 1, but special RS485 to RS232 adapters must be used.

The keypad handler itself is part of the base system, and is called as part of the message handler loop. To allow user configuration, certain P-tables have been reserved for keypad use (refer to section 4.1.9).

4.1.3 Menu Summary

The following table illustrates the overall menu structure

1	Fault Display		
2	Password	1	Set Password Level
		2	Remove Password*
		3	Show Current level*
3	Monitor Variable		
4	Language Selection		
5	Issue Information	1	Firmware Ref.
		2	Core Board
		3	Customer I/O Board
		4	Enhancement Cards
		5	Power Interface Board

* May not be present on all databases

4.1.4 LED Indicators

There are 5 LED's located on the left-hand side of the keypad. These will be under application program control, except in the instance of a watchdog trip, when all LED's will be turned off. The following table shows the B table bits to which each LED is connected. Setting the bit to a HIGH value, will turn the LED on.

LED indicator	Colour	B table ref.	Example Use
Healthy	Green	B32.9	Control Available (L2623)
Running	Green	B32.10	Control On (L2718)
Keypad Control	Green	B32.11	Set when Application Program is using Control Keys (L3101)
Warning	Yellow	B32.12	Battery Warning Light (inverse of A35.0)
Tripped	Red	B32.13	Drive Tripped *

*** Note:**

1 The 'Tripped' lamp will flash when the application program is not running
2 Will flash if the keypad serial link fails
3 Will be off if the user program is running
4 May be configured in the user program to indicate a required condition

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4.1.5 Monitoring and Editing Drive Parameters

The keypad provides the following facilities:

- Monitor the status of the drive (including fault data)
- Monitor the drive variables
- Edit drive parameters. (Temporary "pokes")

Monitoring Variables
Variables can be displayed on the keypad unit together with a text description (up to 16 characters), units and decimal point scaling. The text description is predefined for certain variables (e.g. 'L' tables and certain 'E' tables) and can be defined in the links program for other variables.

Changing Variables
The keypad can be used to change certain 'parameter' variables. These are variables that have been set to a fixed constant as opposed to being linked to another variable. The parameter can have one of a number of different attributes (or editor equivalents) and this also governs the access level. These attributes and access levels are all described in section 4.5.7.

4.1.6 Control Keys

There are four control keys: RUN, STOP, RAISE and LOWER. These are used to stop and start the drive and control the drive frequency from the keypad. These keys act directly on the A table digital inputs table (refer to 4.1.8). The appropriate bit is set high, when the key is pressed, and remains high until the key is released. It will be up to the application program (e.g. Module 31 Test/Local Control) to decide whether to use these keys to control the drive.

Two other keys, which are keypad mode dependant, also affect the A table. These are the ↑ and ↓ keys. If in fault display mode (refer to section 4.1.12), then the status of these keys is reflected in the A table.

4.1.7 Alphanumeric Keys

The alphanumeric keypad contains 19 keys as shown below:

The alphanumeric keys '1A', '2B', '3C', '4D', '5E', '6F', '7H', '8L', '9P', '0S' and '.'. These keys are used to input a table reference, and alter its value, if applicable. (Refer to section 4.1.12)

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ESC	-	Switches to the previous display level
↑	-	Increments parameter numbers or values
↓	-	Decrements parameter numbers or values
?	-	Displays further information
+/-	-	Changes sign of a numerical value
ENTER	-	Terminates entry of required data, and enables modification of value of the variable being monitored
DEL	-	Performs a backspace when in editing mode
Mode	-	Switches between monitoring and modification modes, of a given variable

4.1.8 Digital Inputs/Outputs

The following table shows the table bits, which are set by the keypad, under which circumstances. Note that A34 bits 0 to 6 are set as the logical OR of the statuses of all the keypads connected to the SIGMA. The rest of the bits refer to the states of keypads on each individual serial link.

Table Reference	**Cause**
A34.0	RUN pressed
A34.1	STOP pressed
A34.2	LOWER pressed
A34.3	RAISE pressed
A34.4	↓ pressed and in fault display mode
A34.5	↑ pressed and in fault display mode
A34.6	Keypad connection healthy (refer to section 4.1.10)
A34.8 - A34.11	Link 0 - RUN, STOP, LOWER, RAISE
A34.14 - A34.17	Link 1 - RUN, STOP, LOWER, RAISE
A34.20 - A34.23	Link 2 - RUN, STOP, LOWER, RAISE
A34.26 - A34.29	Link 3 - RUN, STOP, LOWER, RAISE
E9.0 - E9.3	Link healthy for Link 0, 1, 2 and 3
E9.4 - E9.7	Control Passed for Link 0, 1, 2 and 3

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4.1.9 User Configuration

To enable user configuration, tables P10 to P14 have been reserved for the keypad handler.

The format of these tables is as follows:

Table	Format
P10	Default table letter (e.g. 'L')
P11	Table Offset (e.g. 2002)
P12	Keypad Configuration Mask
P12.0	Enable Drive Trip Menu
P12.4	Enable Link 0 disconnection
P12.5	Enable Link 1 disconnection
P12.6	Enable Link 2 disconnection
P12.7	Enable Link 3 disconnection
P13	Unused
P14	Unused

Tables P10 and P11 set up the default table to be monitored, every time the monitor/edit option is accessed from the main menu. If the table letter is set to a '@' (the default), then no table is assumed, and the monitor/edit option will require a table to be entered on entry into the option.

Table P12.0 is used to enable the user to select whether permission is required to remove the keypad. If set, then the Keypad Removal menu option becomes available.

4.1.10 Serial Link Failure

On connection of a keypad to the SIGMA, on any serial link, the healthy bit of the table A34 is set HIGH (refer to section 4.1.8).

If the keypad is physically removed from the SIGMA, a time-out period of 10 seconds is initiated, at the end of which, the keypad is assumed to be removed permanently. This means that on reconnection, the user is returned to the main menu. If P12.0 is set (Enable Drive Trip), and the user has not been given permission to remove the keypad, then (for the appropriate link) the healthy bit will go LOW, and the control passed bit will stay LOW, indicating to the application program, that it should trip the drive.

If the keypad is connected to the SIGMA, and the serial link fails, then the 'Tripped' LED will light and an appropriate message will be displayed on the LCD screen.

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4.1.11 Display Format

The 2-line by 24 character liquid crystal display, can display a full alphanumeric character set.

Initial conditions

When connecting a keypad or on power-up, the first two lines of the main menu will be displayed. (Refer to section 4.1.12). If however the keypad is removed momentarily (e.g. pulled out by mistake), the keypad will display the same screen as at the moment of disconnection. A time-out is incorporated of 10 seconds, such that at the end of the time-out, reconnection of the keypad will bring the user straight into the main menu.

Menu Options

Only two options from a given list can be displayed at any one time. The following shows a typical example:-

```
1. Fault Display
2. Monitor/Edit Params ↓
```

A ↑ character in the top right-hand corner indicates that there are options 'above' the one displayed on the top line. Pressing the ↑ key will then move the menu 'window' up to the next option. Similarly, a ↓ character in the bottom right-hand corner indicates more menu options 'below' the ones displayed and pressing the ↓ key will move the 'window' down one option.

Pressing the given number selects the listed facility regardless of whether the option is visible or not.

Monitoring a parameter

The following diagram is a typical view of the LCD display, when monitoring a parameter:-

```
L2002 = 56.23 %        U
Speed A F/B            ?
```

The first line contains the table letter and number (including a specific bit position, if required), followed by the value and its associated units. The letter in the top right-hand corner indicates the attribute of the link.

The second line displays the comment attached to the table, either from the database, or a DEF TABLE statement within the links program. A '?' at the right-hand side, indicates that further information exists about the monitored table (refer to section 4.1.12).

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4.1.12 Functions of The Keypad

On power up, or plugging in of the keypad to an already powered up drive, the keypad will display the first two lines of its main menu of facilities. Pressing ↑ or ↓ scrolls up and down the menu as required. The facilities are as follows:-

1. Fault Display
2. Password Facilities
3. Monitor/Edit Parameters
4. SIGMA Language Selection
5. Display Issue Information

If P12.0 is set (refer to section 4.1.9), then pressing <ESC> twice takes control into the 'Remove Keypad Menu'.

Fault Display
On entry into this facility, the keypad will interrogate the drive, and first check to see if there are any system messages. It will display these messages only. If a system message is present, then the application program will not run, so application messages are not available to be displayed.

If no system messages are present, and the user program is running, then the fault display module is interrogated (if part of the application program), and any trip messages are displayed, along with a trip number. The message '1st FAULT' is used to denote the first fault message. This assumes that there will only ever be one master fault display module called as part of the application program.

If no trip messages are found, or the fault display module is not called as part of the user program, then other application modules messages can be displayed. Any application module can potentially send a message to the keypad/monitor. These will also include any alarm messages from the fault display module.

If no messages of any form are found by the keypad, then a message 'NO MESSAGES AVAILABLE' is displayed.

Pressing <ESC> returns control to the main facilities menu.

The ↑ and ↓ keys can be used to scroll through the messages, but it is up to the application user program to read the A table bits, set by these keys, and copy them to the fault display module.

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Password Facilities
See also section 4.5.7.

This section presents the user with the following two choices:

1. Set Password Level
2. Remove Password

On entry into option 1, the user is asked for the required password level, for which a password will be entered. Only the numbers '0' to '3', and <ENTER> are valid. If <ENTER> is pressed, the access level is set to 0 or 1, dependant on the value of E0.15 (refer to 4.5.15).

Entering a valid password level, displays the message 'ENTER PASSWORD'. The user must then type in a password, which has been previously set up by CSP or OVERVIEW. The keypad handler will then decide which access level (refer to section 4.5.7) to grant to the user. If an un-recognised password is entered, a message 'INCORRECT PASSWORD' is displayed, and the user is prompted to try again.

A password is always made up of 4 digits, terminated by <ENTER>. The digits are not printed to the display, but a '*' will appear after each keystroke. Pressing <ESC> will return control to the main menu.
e.g.

```
ENTER LEVEL REQD:   2
ENTER PASSWORD:   ****
```

On choosing option 2, the password level is removed, and the access level is set to either 0 or 1, depending on the state of E0.15 (see section 4.5.7). This effectively removes all access rights, except to the safest of links.

A password time-out facility is incorporated (see section 4.5.7).

Monitor/Edit Parameters
On entry into this option, one of two things will occur. If the default monitor variable tables have been set up correctly (see section 4.1.9), then the display will monitor this value immediately. Otherwise, the keypad displays the message 'ENTER VARIABLE'. It then waits for a table address to be entered. i.e.

```
ENTER VARIABLE
```

The first key stroke of the alphanumeric keys (1A, 2B, 3C, 4D, 5E, 6F, 7H, 8L, 9P and 0S) is interpreted as a letter and subsequent ones as numbers. After the first key press, the 'ENTER VARIABLE' message is removed, and the keystrokes are copied directly to the first line of the display. The address entry is terminated by <ENTER>.

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After the first keystroke, the ↑ key will scroll the letter backwards through the alphabet, towards 'A', and the ↓ will scroll the entered letter forwards, towards 'Z'. In this way all the tables may be accessed. When the address entry is complete, the reference is validated. If the entered address is that of a valid table location, the contents of that address are displayed as a decimal number with units and data comments. Otherwise, the message 'NO SUCH TABLE' is displayed, before re-prompting the user for a new table.
e.g.

```
L2106  =  28.53%
U
SPEED REF
```

When monitoring the data table the following key presses will have the given effects:

Pressing ↑ (Previous) or ↓ (Next) will scroll the display backwards and forwards through the data table.

Pressing <ESC> while monitoring, returns control to the main facilities menu.

A '?' symbol in the bottom right corner of the display indicates that further information is available about the currently monitored variable. Pressing '?', will bring up the information. The table comment is over-written with each new piece information. The '?' symbol remains displayed whilst there is further information to display. Only the maximum and minimum values of the table (if defined as non-default values) are displayed. Pressing <ESC>, redisplays the parameter comment.

Pressing <ENTER> or <Mode> enables the modification of the value of the variable being monitored. Note, this modification is a temporary modification only, it will disappear the next time the program goes from Halt to Run, e.g. switch on. This function is only available when monitoring a variable in decimal format. If the link is not to a constant, the message 'LINK NOT TO CONSTANT' is displayed on the second line. The symbol comments are redisplayed after the error message is removed. Note, this does not work if the user is in the "display information mode" (i.e. after pressing ?) the user must first <ESC> out of that mode.

If the access level is insufficient to edit the variable, the message 'INSUFFICIENT ACCESS LEVEL' is displayed. Otherwise, this function causes the data comments field on the second line, to be replaced by the message 'NEW =' so that new data may be entered. Pressing <ENTER> updates the value of the link, and waits for a new value to be entered. Pressing <ESC> or <Mode> during entry of the new value leaves the original data unchanged, and returns control to the monitoring of the variable.

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Function Keys

Pressing the <.> (i.e. the decimal point) on the keypad, enables access to the function keys of the keypad. A symbol ^{F}n (made up of an 'F' and an 'n') will appear in the bottom right corner of the display, to show that the next key will be interpreted as a function key. If an invalid key is pressed, the symbol will disappear. The valid keys are as follows:

Key	Function
D	Monitor in Decimal (includes scaling and units)
H	Monitor in Hexadecimal (begins with a '@' and includes units)
B	Monitor in Binary (displayed as a series of '.'s and '|'s)
S	Scope Output (see 4.1.13)

The B, H and D keys alter the base of the displayed data. For non-decimal displays the decimal point is ignored and the data displayed as if it were an integer. Refer to section 4.1.13, for details on monitoring variables using an oscilloscope, using the scope output function.

With a data table location displayed, entering another data table location will display the new data table location. <ESC> is *not* pressed first.

SIGMA Language Selection

A SIGMA database can store comments in fifteen different languages. However, only the English language is available at this time. Comments in up to two of these languages may be downloaded to the drive. The available languages are set up within the application program. To alternate between the two languages, this menu presents the user with those languages available, and an arrow pointing to the current selection:-

```
    1.  English
->  2.  Francaise
```

Pressing the appropriate number selects the associated language.

Display Issue Information

This option will present a sub-menu, giving the user the ability to view the current firmware database reference, and the information about each attached board. This data is stored in the serial E^2PROM, located on each board. This facility is only valid provided the board has been programmed with the appropriate data.

The options are as follows:

1. Firmware Ref.
2. Core Board
3. Customer I/O Board
4. Enhancement Cards
5. Power Interface Board

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The firmware reference gives an indication of the software running within the drive controller.

An example of a firmware reference display would be:

```
Database Firmware Ref:
     GDS1106-6004C
```

On choosing the Enhancement and Power Interface Board, the user is asked which card number is to be examined. There are 4 Enhancement cards and 3 Power Interface Boards available. If the chosen card is not present, a message 'CARD NOT PRESENT' is displayed.

The issue information is displayed in a compact style, due to the size of the LCD display, and is of the following form:

```
[OIS No & Product Ref.] [Board Ref.]/[Comb No] [EEPROM
                        Issue]
 [ENU Status]        [Author]      [Modification Date]
```

An example of a board/card information display would be:

```
GDS2005-4017  4494/20 A
010/2/B              MJC
12/10/1997
```

Keypad Disconnection
This option, when accessed, presents the user with the following two choices:

1. Keypad Disconnection
2. Return To Main Menu

Choosing option 1, will request keypad removal. If the relevant P12 bit is set (refer to 4.1.9), enabling disconnection, then the keypad will display an appropriate message, and set the appropriate bit of E9 (refer to 4.1.8). Pressing <ESC> will return the user back to the main menu, if removal is not required. If removal is prohibited, then an error message will be displayed, and control will pass back to the main menu.

Choosing option 2, returns the user to the main menu.

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4.1.13 Scope Output

Pressing the <.> then <S> keys when monitoring a variable, connects that variable to a scope output. The user is asked to type in the number of the output (0-3) on the Analogue Termination Unit, given that the outputs are available for scope monitoring. Pressing <ENTER> accepts the choice, <ESC> aborts the operation. If the output is already in use as an application output, an error is indicated by displaying the message 'SCOPE OUTPUT *n* NOT AVAILABLE', where *n* is the number entered, and the user prompted again. On choosing a valid scope output, the user will be requested to enter the offset and scaling values. By pressing <ENTER>, without entering any other digits, the current value will be used.

The scope output may be set by:-

- Keypad (as defined by this section)
- By setting E tables in the links program or via the CSP monitor (see section 4.5.15)

4.1.14 Keypad Error Messages

Displayed Error Message	Reason / Comment
NO MESSAGES AVAILABLE	There are no system, trip or alarm messages present.
INCORRECT PASSWORD	An un-recognised password was entered.
OUT OF RANGE	The newly entered value is outside the range set by the maximum and minimum values.
LINK NOT TO CONSTANT	The monitored link is not set to a constant value in the links program, and therefore cannot be modified.
WRITE ACCESS DENIED	The drive permissives are incorrect, and therefore the value cannot be modified.
UNABLE TO MODIFY TABLE	Another serial link has locked out the keypad, and modification is temporarily disabled.
INSUFFICIENT ACCESS LEVEL	The user has tried to modify the value of a parameter of which he doesn't have the authority to do.
CARD NOT PRESENT	The chosen interface card is not installed within the SIGMA controller.
NO SUCH TABLE	The data table number is not within the size of the data table.
SCOPE OUTPUT n NOT AVAILABLE	Having entered either 0, 1, 2 or 3 for the scope number (refer section 4.5.15) the base system reports that it is being used.

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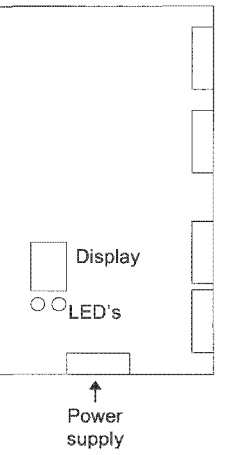
IP7015080



IP7015081

IP7015082

IP7015083

F1=1 **Code area corruption**

Fault Summary
A section of code has been corrupted. The controller execution could become unpredictable. Further information is held in F2, as follows

F2=1 Base System code fault
F2=2 Fast task Code
F2=3 V table data
F2=4 User Program Corruption
F2=5 Pre-set Table Corruption
F2=6 L Table descriptor Corruption
F2=7 Fixed data area

Further Details
The areas given above are CRCed, and the value held in memory. The CRC is calculated for each block at two points in the program

- On a Halt - Run.(which also occurs at power up)
  All areas are checked at this point
- As part of the background self checks
  10 bytes of the block are calculated at a time. When a whole block has been CRCed the value calculated is checked against the value held in memory. If the values do not match, then the watchdog is tripped.

  Because each block is checked in turn, and only 10 bytes are calculated at a time, a corruption of memory will not be calculated immediately.
  For example:
  Total size of all areas = 100kbytes
  Scan time = 2ms
  Worst case time for detection = 20s

Possible causes

- Genuine fault on board. If the fault is persistent the board should be replaced and returned to supplier
- Error in firmware has changed a code area. If the fault occurs even after the spare is fitted then contact ALSTOM Power Conversion
- Excessive noise has corrupted memory on core board. Fault occurs when contactors switched or other 'noisy' action occurring
- Fault in battery backup has not retained code properly. Fault occurs when switching system on. Note that the battery may be flat. Replace battery and reload program

Note that since the bootup code held in EEPROM checks the validity of the base system code and V tables, a corruption in either of these will result in the system starting up as if it is a clean system. The exception to this is on older boards, where a code area corruption (F1=1, F2=7) was reported but where the code was valid when the system was powered off and back on (no code download required). These boards should be returned to the supplier for upgrading.

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F1=2	**Symbol table corruption** **Fault Summary** A fault has been detected in the table that holds the comments, scaling and access levels. Further information is held in F2, as follows 1 Symbol Table Corruption 2 Attribute Table Corruption **Further Details** The areas given above are CRCed, and the value held in memory. The CRC is calculated for each block at two points in the program • On a Halt - Run.(which also occurs at power up) All areas are checked at this point as part of the background self checks. 10 bytes of the block are calculated at a time. When a whole block has been CRCed the value calculated is checked against the value held in memory. If the values do not match, then the watchdog is tripped. Because each block is checked in turn, and only 10 bytes are calculated at a time, a corruption of memory will not be calculated immediately. **For example**: Total size of all areas = 100kbytes Scan time = 2 ms Worst case time for detection = 20s **Possible causes** The causes of this fault are similar to those for F1=1.
F1=3	**Stack Overflow** **Fault Summary** There has been an internal error that has resulted in the end of the stack being written to. Further details are held in F2 as follows 1 Base System Stack 2 Interrupt Stack F3 contains the stack index that has been corrupted.
F1=4	Not used
F1=5	Not used
F1=6	Not used

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F1=7	**Fast task failure** **Fault summary** A failure has been detected when the fast task has been initialised. The fast task will not be executed. Further data in F2 as follows: 1 Initialising error F3 = error code any other value Error in fast task while running **Further details** The fast task returns a non zero value after initialisation, normally the XILINX error code. F2 is set to 1 under these circumstances, with F3 holding the returned error code. If the fast task trips the watchdog while running, further data is given in F2 - F5, and must be communicated to the fast task designer. **Possible causes** A fault with F2=1 is generally due to a fault in the programming of the XILINX. The value in F3 will help the fast task designer to diagnose this problem.
F1=8	**RAM failure** **Fault summary** Two types of RAM are fitted to the SIGMA board - FAST & SLOW Ram. Both types of RAM are checked by writing a pattern to them and then reading that pattern (the contents of the RAM address are first saved). F2 indicates the RAM that has failed 1 Fast RAM failure 2 Slow RAM failure F3 = Address that the failure is detected at. Record in Hex. **Further details** The RAM checks are performed as part of the background self checks. A small chunk (10 bytes) of fast and slow RAM is checked each time. If the pattern written is not the same as the pattern read then the watchdog is tripped. **Possible reasons** This points to a genuine problem with the hardware. The address at which the failure occurred should be included when the board is sent back for repair (record F2 & F3 in Hexadecimal).
F1=9	Not used
F1=10	Not used
F1=11	Not used

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F1=12 **XILINX Dual port RAM failure**

Fault Summary
The Power up RAM checks have detected a fault in the XILINX interface RAM to the SIGMA core electronics.
F2= failure address. Record in Hex.

Further details
The Firing pulses are generated by a XILINX LCA device. Data is transferred to this device via Dual Port RAM. This RAM is checked as part of the initialisation sequence, by writing a pattern to it and then checking that the pattern read back is the same.

If there is a discrepancy, then the watchdog is tripped.

Possible reasons

- There is a genuine fault with the hardware. The fault will always occur under all circumstances.
- There is a fault in the firmware. This is indicated by the fact that the fault does not occur when a new system is downloaded to a 'clean' board (batteries have been removed and the board powered off).

F1=13 **Watchdog Confidence check fail**

F2 has Further details

F2=1 **Failure on Initialisation**
F3 has further details

1	Coil is on when it should be off
2	Contact is closed when it should be open
3	Watchdog coil not energised when requested
4	Watchdog fails to trip if triggered too soon
5	Watchdog fails to trip if never triggered
6	Watchdog coil has failed to energise
7	Watchdog contact has failed to energise

F2=2 **Self Test failure**
The watchdog circuits are tested periodically to ensure that they have not failed.
F3 gives further details of the fault

1	Testing watchdog when it is already tripped
2	Watchdog failed to trip when triggered too soon
3	Watchdog fails to pick up after above test
4	Watchdog has tripped too soon on 'no trigger' test
5	Watchdog fails to trip if never triggered
6	Watchdog fails to pick up after above test

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F1=14 **Basic I/O failure**

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	F2=6	**Basic I/O Cross Check failure** **Fault Summary** Customer I/O input A32.7 (the 'fast' digital inputs) is also read in via an 'invisible' byte of the BASIC I/O Address 1. Outputs B1.8, 10, 12, are read back in the same invisible byte. If there is a discrepancy between the read back values and the actual values for more than 100ms, then the watchdog is tripped. This function also provides an interlock on the ribbon cables between the core board and the Customer I/O Board. Further details are held in F3 (A32 bits), F4 (Read back value) and F5 (B1 table bits).
F1=15	Not used	
F1=16	**Power Supply failure** **Fault Summary** Various on board supplies are monitored. If the supply exceeds a given range (see section 4.5.14 for details) for more than 100ms then the watchdog is tripped. Data is stored in F2 as follows: F2 = associated C table (or -1 if there has been an I/O processor input failure) F3 = Value that caused the trip. (Not relevant if F2 = -1)	
F1=17	**General fault handler** **Fault Summary** This trip is generated if a call to the control processors fault handling procedure is made. This procedure deals with such faults as illegal processor level code and addressing faults. The fault indicates a serious failure in the control processor. The following F tables should be noted (hex values): F2 = Fault type F3 = Fault sub type F4 = Address of fault (view in hex) **Fault types & Sub types** **F2** — **F3** 2=Operation — 1 = Invalid Opcode 2 = Operation 3 = Unaligned fault 4 = Invalid Operand 5=Constraint — 1 = Constraint range 2 = Privileged	

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IP7015089

	7=Protection	1 = Length 4 = SRAM Protection
	10=Type	1 = Type
F1=18	**Flash programming error** **Fault Summary** If the backup to FLASH facility is enabled (P9.5=1) and the 'Trip watchdog on error' permissive is set (P9.6=1) then a fault in programming the flash will trip the watchdog. The code in F2 should be noted and passed to the issuing authority.	
F1=19	**Hardware Trip** **Fault Summary** Most watchdog trips are due to faults detected by the firmware, which then trips the watchdog relay via a 'watchdog trip code'. If the watchdog relay has tripped without a fault code being present, this fault code is generated. The fault indicates that the watchdog circuit has been triggered outside its trigger window of 40ms - 60ms, or has not been triggered at all. This is normally due to a failure of the fast task, indicated by the decimal point on the 7 segment display fitted to the core board not flashing.	
F1=20	**I/O processor failure** F2 gives further details	
	0	960-166 handshake failure
	1	Fatal I/O processor fault
	2	Internal error
	8	Code failure
	9	Internal RAM failure
	10	Dual port RAM failure
	11	Local RAM failure
	14	IOP watchdog failure
	15	Background test failure
	The contents of F3 - F5 should also be noted (in Hex).	
F1=21 to 31	Not used	

Trips 32 onwards cannot be masked out and will always trip the watchdog.

F1=32	Not Used
F1=33	**Slow task scanning failure** **Fault Summary** A handshake is performed between the fast task (which runs at an interrupt level) and the base level. If the base level does not respond within 10 seconds then the watchdog is tripped.

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F1=34 **Board Incorrect**

Fault Summary

A check is made that the firmware is running on the correct core board and that the OIS numbers defined in the links program and the OIS numbers held in the serial EEPROMs fitted to the core board and its attached peripherals are correct (provided that the links program OIS numbers are non zero).

If there is a discrepancy then the watchdog is tripped.

F2 - F5 give further details:

F2 = Core board number
F3 = Core board number required by firmware
F4 = OIS valid bits

If the OIS check between the values defined by the links editor and the values read from the serial EEPROMs at power up are different then the associated bit in the OIS_CHECK variable (V231) is set off. This variable is copied to F4. The bits are as follows:

Bit 0 = Core board
Bit 1 = Customer I/O Board
Bits 2 - 4 = Power interface boards
Bits 5 - 8 = Enhancement boards

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4.4.1 Catastrophic Watchdog Failure

There are occasions when the system fails in such a way that the serial links no longer operate. Under these circumstances it is impossible to determine the cause of failure, since no watchdog fault codes are available. Because the 'F' tables are cleared on power up a watchdog trip puts a copy into the read only 'V' tables. The offset of these tables are defined by F0:

e.g. if F0 = 250
F1 copy in V250
F2 copy in V251

In this way the cause of a watchdog trip can be determined even after the controller has been powered off and back on.

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4.5 DATA TABLES

4.5.1 Introduction

The data tables are the areas of memory accessible to the user program. Each location in the data tables is a variable, which is a 32-bit integer binary word.

4.5.2 Data Table Addressing

Each data table address refers to a unique memory location. All addresses are a letter (the table) followed by a number (the variable).

E.g. A20, G1500, P60 etc. to refer to a whole word.
or A20.1, J15.2 etc. to refer to a bit in a word.

There are two ways of interpreting the variable number depending on the table.

1. L Tables are the SIGMA module tables (see below). The numeric part of the table reference defines both the module number and the variable in the module.
2. All other tables are like a GEM80. The numeric part of the table address refers to the element in the table.

The table in section 4.5.12 provides a summary of the different data tables.

4.5.3 SIGMA Data Tables (L Tables)

The SIGMA data tables are defined by the SIGMA MODULES. The L Table is not a contiguous block of memory as it is for GEM80 tables but is in sections for each of the modules.

A reference to the L Table is always in the form:

(letter) (module number) (variable number)

Letter is L
Module number is up to three digits 0 to 655
Variable number is two digits 00 to 99

On the programmer it is possible to monitor bits in an L Table and bits in an L Table can be used in ladder instructions (N/O, N/C contacts). However considerable care should be taken to ensure the results are as expected.

It is not allowed to output to bits in an L Table in the ladder (i.e. COIL).

L Table locations are read only for ladder special functions, e.g. MOVE.

L Tables may not be used in SEQUENCER, DELAY or COUNT. (They can be used in the value following a DELAY or COUNT.)

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4.5.4 Other Data Tables

All tables other than L Tables are similar to GEM80, except that they are 32 bit tables as opposed to 16 bit tables. Whether a variable is numeric or logic is determined by the user in the program.

4.5.5 Values

Values are interpreted in the following way:

Integers
Numbers in the range -2147483648 to +2147483647.

There may be a scaling factor e.g. scaling factor of 2 gives a range of -21474836.48 to +21474836.47 (a scaling factor divides the value by 10^n).

(Note the range may be smaller if there is a limit value for the variable).

Hexadecimal format
Up to 8 character number preceded by @ symbol range @00000000 to @FFFFFFFF.

Note that only decimal numbers are displayed and accepted by the keypad and as values when entering parameter links.

Logic values
For bits 0 = false
1 = true

For logic L Table variables values are interpreted as

0 is false
<>0 is true

When entering parameter links for logic L Tables

0 = false
1 = true
all other values are treated as invalid.

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4.5.6 Attributes

Each variable and each link statement, may have various attributes:

Variable Attributes

Type	logic or integer
Read only	It is write enabled if it is an input to a module
Scaling	Determines the position of the decimal point
Max, Min	Limits of variable. The value of the variable is limited to these settings by: • Code generated by the drive compiler on each link defined in the LINKS EDITOR • Any ESP command to read or write the data table
Default	The variable is either set to 0 or a default value at power up or HALT-RUN
Access	A value 0-6 defining the access level (See section 4.5.7)
Comments	Up to 15 characters for a comment
Units	Selected from the predefined list, see section 3.3.3

Only inputs may appear on the LHS of a link.

The attributes for L tables are found with the diagrams, which describe the functions of the modules. Refer to the Control Module Data Sheets in a separate document.

The attributes can also be defined by the DEF TABLE statement in the Links Editor.

Link Statement Attributes
Each link statement has an attribute, which is associated with the access level required for that statement to be edited. These attributes are listed below in the next section under the column heading Editor Equivalent.

4.5.7 Access Levels

The following access levels are applied to each variable:

Access Level	Description	Change permissive	Password	Link Statement Attribute
0	Unlocked	No permissives required	No password	U
1	Safe	Change when E0.15=0	No password	S
2	Password	No permissives required	Password 0	P
3	Password Safe	Change when E0.15=0	Password 0	Q
4	Locked	Change when A32.7=0	Password 1	L, *, C_1
5	Engineer	Change when A32.7=0	Password 2	E, C_2
6	No change	Change when A32.7=0	Password 3	N

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Notes:

1. The attribute 'C' has a different access level, dependant on the drive status. 'C_1' is the access level when in commissioning mode, and 'C_2' is the equivalent when NOT in commissioning mode. Also, access level 6 (No change) literally means that the value can only be changed by an engineer with knowledge of the highest password level. This will normally be reserved for development engineers.

2. Access Level takes into account both the password level, and the drive status (for example A32.7).

3. If no keys are pressed for a time-out period of five minutes, the lowest level of password is assumed.

CSP Monitor
Warning, When using the CSP Monitor function, the access levels listed for the keypad do not necessarily apply. Certain values may be "poked" when the drive is running.

CSP Editor
When using the CSP links editor, the editing is carried out off line, therefore the access levels do not apply, but the password levels do.

4.5.8 Table Allocation

The data tables which are not predefined (fixed) are allocated during compilation depending on reference to table locations in the ladder part of the program.

L Tables are allocated for the whole of a module if there is a reference to any variable for that module in the ladder.

Thus for control micro modules the value following the S140 special function causes table space to be allocated for that module. For fast task modules the tables are allocated automatically for those modules included in the fast micro type selected and no specific reference to the module is needed in the ladder.

For other data tables space is allocated up to the highest table location referred to in the Ladder or Links.

4.5.9 Data Table Protection

Data tables can be accessed either from the keypad or from a PC. All data tables can be read. Editing of the data tables is constrained by the following rules:

All tables can have a defined write protection or edit protection. This is defined at two stages:

- **Design Time**
  The write protection/edit protection status can be defined for a data tables location by the designer.

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- **User programming**
  The user can set the access level attributes of a link in the user program.

4.5.10 Data Table Initialisation

Data tables are initialised at the following points:
- On power up
- On a HALT to RUN

The initialisation of a data table consists of the following:
- The data tables are cleared to zero (except for certain defined tables, see section 4.5.12 for details)
- Tables with non-zero values defined in the pre-set table are initialised to these values. The pre-set table contains a list of variables and their values as defined by the following:
  - Certain SIGMA application module variables have default values defined. See the specific application module documentation for the values of these variables
  - Certain system variables have non zero default values. These are defined in the table listings in sections 4.5.13. to 4.5.19.
  - Default values can be defined by using the Link Editor 'DEF TABLE' statement
  - Values linked to a constant in the Links program are placed in the pre-set table

Variables initialised to a pre-set value can be overwritten by subsequent links to a variable in the user program.

4.5.11 Data Table Updating

Data tables are updated at the point of execution in the user program. L tables outputs are updated when their module is updated. L table inputs defined by the Ladder program are updated at the point of execution in the user program. L table inputs defined by links in the Links program are updated immediately before the execution of the module.
All other links (including inputs to fast task modules) are executed at the end of the user program, in the sequence in which they appear, in the Links program.

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4.5.12 Table Summary

Function	Data Table	Content	Minimum Size	Maximum Size	Cleared to zero at halt to run	Cleared to zero at power on
digital inputs	A	Input values from Basic I/O highway and isolated digital input terminals	Fixed 36		YES	YES
digital outputs	B	Output values for the Basic I/O highway and isolated digital output terminals	Fixed 33		YES	YES
analogue inputs	C	values from A to D convertors	Fixed 32		YES	YES
analogue outputs	D	values from D to A convertors	Fixed 4		YES	YES
Timing & Flags	E	System information written by the controller	Fixed 400		YES but then updated	YES except time
Fault Codes	F	Written to by failure routines	Fixed 200		YES	YES
General Workspace	R	Available for counters & sequencer etc. Only cleared when power first applied to the system	1		NO	NO See note 1
	W		0		NO	NO See note 1
	G O H Q N U	General data	0		YES except when R0.0 = 1	YES

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Function	Data Table	Content	Minimum Size	Maximum Size	Cleared to zero at halt to run	Cleared to zero at power on
serial links	I J K	Data transmit lengths Data received Data for transmission	Fixed 12 Fixed 600 Fixed 600		YES	YES
predefined word-space	L	SIGMA module tables	0	up to 100 per module	YES except when R0.0=1	YES
Maintainer	M	Available for user programmed tests	0		YES except when R0.0=1	YES
Pre-set	P	System pre-set values. P0-99 reserved	100		YES	YES
System Table	V	Controller firmware workspace: Read only	Fixed		NO	NO

General Note

The 'clear store' command clears all data tables, the program and the firmware. All data tables are cleared to zero if:

- Data table size allocation changes
- New system loaded

Application Note

- N and O tables generally used by comms enhancement cards
- W tables used for variables to be retained through power down
- G tables are used for general workspace
- M tables used for ladder testing (including built in test facilities)

4.5.13 A/B Tables

BASIC I/O Tables (A/B 0 to 15)

The function of each address is determined by reference in the user program. The same address cannot be an input and an output. An error is flagged if this occurs.

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Some of the Basic I/O is already predefined by the customer I/O board, as follows.

A0	bits 0-7	Plant identity
	bits 8-11	Link 0 tributary number
	bits 12-14	Link 0 baud rate
	bit 15	Reserved
A1	bits 0-7	Dedicated inputs via Customer I/O Board
B1	bits 8-15	Dedicated outputs via Customer I/O Board

Other logic I/O

A32	bits 0-7	Fast digital inputs
A33	bits 0-15	Power Interface Board status feedbacks. For example may be used in conjunction with the Pulse Amplifier for Mk.10 Convertors

A34 Keypad local control (see also section 4.1.7)

A34.0	RUN
A34.1	STOP
A34.2	LOWER
A34.3	RAISE
A34.4	Down arrow (L3276 Next)
A34.5	Up arrow (L3277 Previous)
A34.6	Keypad healthy: 1= healthy, 0= disconnected
A34.8-A34.11	Link 0: RUN, STOP, LOWER, RAISE
A34.14-A34.17	Link 1: RUN, STOP, LOWER, RAISE
A34.20-A34.23	Link 2: RUN, STOP, LOWER, RAISE
A34.26-A34.29	Link 3: RUN, STOP, LOWER, RAISE

Note that A34 cannot be viewed using the keypad or the MONITOR unless P12.16 is set on.

A35 System status bits

A35.0	Battery Healthy:	0 = battery low
A35.1	Watchdog closed:	0 = Watchdog tripped
A35.2	Micro power fail warning: Occurs 20 ms before power fail. 0=fail	
A35.8-A35.15	misc. bits	

B32 Digital outputs (see also section 4.1.4)

B32.9	keypad/display user lamp 1	'Healthy'
B32.10	keypad/display user lamp 2	'Running'
B32.11	keypad/display user lamp 3	'Keypad Control'
B32.12	keypad/display user lamp 4	'Warning'
B32.13	keypad/display user lamp 5	'Tripped'

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4.5.14 C/D Tables

C Table	Description	Range
0 - 2	Fast analogue inputs; function determined by PIB	
3 - 6	Multiplexed input; function determined by PIB	
7	Plug Interlock;	0 = healthy
8, 9	Multiplexed input; function determined by PIB	
10	OV ref.	-491 to + 491; Nominal = 0
11-13	Fast analogue inputs; function determined by PIB	
14 - 20	Multiplexed input; function determined by PIB	
21	Analogue 5V Ref.	15564 to 17203; nominal = 16384
22	10V ref.	348 to 425; nominal = 387
23	3V ref.	576 to 640; nominal = 614
24	5V ref.	486 to 537; nominal = 512
25	Temperature #: Conversion equation given by: (4.2 - (C25 * 5 / 1024)) / 0.0315 deg. C	
26	Battery Volts	3V to 6V (614 to 1228)
27	-15V/+15V	428 to 735; nominal = 582
28	+15V ref.	512 to 576; nominal = 539
29	-5V ref.	160 to 224; nominal = 195
30	5V supply	486 to 537; nominal = 512
31	0V ref.	0 to 82; nominal = 0

The temperature monitored is that of a chip on the board. The recommended maximum temperature is 55°C. This numeric value may be used in an application ladder program to give the required protection. 55°C corresponds to the numeric value of C25=505.

D0	Analogue output 0
D1	Analogue output 1
D2	Analogue output 2
D3	Analogue output 3

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4.5.15 E Table

E0	System flags		
	E0.0	0.1 sec timing marker -	set on for one scan every 100ms
	E0.1	1 sec timing marker -	set on for one scan every second
	E0.6	Recompile flag -	set on for one scan for successful halt-run
	E0.10	Basic I/O Inputs updated	
	E0.14	Reserved	
	E0.15	User programmed 'Drive running'; 1= Running, 0= Stopped, Default = 1	
E1 - E6	Calendar clock		
	E1	Seconds	
	E2	Minutes	
	E3	Hours	
	E4	Days	
	E5	Months	
	E6	Years	
E7	Last scan flag: Last scan time in 1 μs units		
E8	Calendar adjustment; (not used)		
E9	Keypad bits (see section 4.1.9).		
E10	Overrun count. Incremented each time scan time exceeds time set in P1		
E11	System flags		
	E11.0	Run flag	
	E11.1	Test flag	
	E11.2	Commissioning flag	
	E11.3	Single scan flag	
	E11.4	Writing to FLASH	
	E11.5	FLASH error	
E12	Div. zero flag: Set each time there is a div. by zero interrupt.		

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E13	Scope output 0 scaler	Default = 3052 (which gives 10V = 10,000)
E14	Scope output 0 offset	
E15	Scope output 1 scaler	Default = 3052
E16	Scope output 1 offset	
E17	Scope output 2 scaler	Default = 3052
E18	Scope output 2 offset	
E19	Scope output 3 scaler	Default = 3052
E20	Scope output 3 offset	

The default scaling of 3052 gives 10V out for a 10,000 value. If the variable is 0-100,000 then the default needs to be edited to 30520

E21 Drive ID

E22-E25 Scope output config.

To select a scope output, set the 'Letter' to the data table letter, and the address to the data table address

Note:

The letter can be entered via the monitor by preceding the letter with a '

To enter the letter in the links program, it must be within ""

E22	Scope 0 letter
E23	Scope 0 address
E24	Scope 1 letter
E25	Scope 1 address
E26	Scope 2 letter
E27	Scope 2 address
E28	Scope 3 letter
E29	Scope 3 address

Scope output = <u>(data table & address + Offset) x 10000</u> / Scaler

Note, Data Table is e.g. L
Address is e.g. 2140
Offset is the numeric offset

When the scope outputs are used, the values in D0, D1, D2, D3, contain the scaled and offset adjusted values written to the digital to analogue convertor.

A scope output may be used as long as there is no Ladder or Link statement writing to the particular D table for that analogue output. Additionally, scope outputs are only active if they reference a valid data table location. The monitor mode of the CSP may be used to "poke" D table locations 0 to 3 for analogue output test purposes, provided the particular scope output is not active.

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Example of scope output:
To output the location L10107 to analogue output DO, write the following:

Using Monitor
E22= L *(press ' before pressing L, then display in text mode when using CSP Monitor; note, depending upon the base selected, initially this may display as 76, i.e. the number for the ASCII code).*
E23= 10107
This will apply a temporary 'poke'

Using Links editor
E22= "L"
E23= 10107

Using Keypad Function Key
Refer to section 4.1.12

E30	Boards present
E31 - E319	Board OIS data, (current and future firmware)
E320 - E369	Spy module
E370 - E377	Scope output scaling for D4 to D7. Use in similar fashion to E13 to E20
E378 - E385	Scope output address for D4 to D7; Use in similar fashion to E22 to E29
E386	FLASH bytes used (% of overall available space)
E387	FLASH: bytes free
E388	FLASH user control: E388.0 Program FLASH E388.1 Clear FLASH

4.5.16 F Table - System Fault Table

F0	Not used	
F1	Watchdog trip reason	(See also the watchdog trip information in section 4.4).
F2-F5	Watchdog trip; additional information	ditto
F6	Watchdog Trip 0-31 bits	
F7	Watchdog trip 32-63 bits	
F8-F21	Supply values	
F22	Divide by zero data	
F37-F49	Serial link counters	
F50-F119	Serial link statistics	

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4.5.17 I Table

These tables are used for control of the serial links when in table exchange mode

I0,I1	Serial link 0 transmit and receive lengths
I2-I9	Serial link 1 transmit and receive lengths to up to 4 secondaries
I10-I11	Serial link 2 transmit and receive lengths

4.5.18 J/K Serial Link Table

J0-J99	Serial link inputs via serial link 0
J100-J499	Serial link inputs via serial link 1
J500-J599	Serial link inputs via serial link 2

K tables follow the same numbering.

4.5.19 P Table

P0	Unit Identification number:	Lower 12 bits cross checked with drive ID. Check on start up if P8 is non zero.
P1	Scan time in 1 millisecond units, with a resolution of 1μs. Max of 65ms	
P3	Fault flags mask	
P5	Units of delay function; Minimum of 1 ms: Default 1 ms	
P8	Non zero to enable drive identity check	
P9	System settings P9.0 1 = Enable 'Run on power up' P9.1 1 = Disable RAM tests P9.2 1 = select 4495 Customer I/O P9.3 Reserved **Flash programming. See section 2.6** P9.4 Run and program FLASH together P9.5 Backup RAM to FLASH P9.6 Trip watchdog on FLASH error P9.7 Pack code into FLASH All other bits must be set to zero	
P10-P12	Keypad Configuration data	
P13-P14	Reserved	
P15	Configure enhancement boards (now replaced by P25-P28)	
P16	Reserved	
P17	Reserved	
P18	FLASH programming block size (in bytes)	
Note:	Changes to P0 - P19 do not take effect until there is a halt-run transition. This means that changes cannot be made by 'poking' value from the keypad or the monitor. Any changes required must be entered into the user program and the program compiled and downloaded.	

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P20-P23	Source code time and date stamp Set by compiler for issue D of CSP tools
P25 - P28	Enhancement card configuration - see section 1.7
P100	Onwards available to user. Used for messages. For other than messages, G tables are generally used

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5. ORDERING DETAILS

Check with ESG for most up to date information.

5.1 SIGMA CORE

Hardware	Order Code
SIGMA core board & moulding without keypad	GDS1002-4006
Above system in packing carton for supply to BEI companies	GDS1002-4004

5.2 CUSTOMER I/O BOARD

Hardware	Order Code
Customer I/O (old type)	Discontinued
Customer I/O assembly(new type) - includes 20X4454/10 analogue termination panel and 20X4495/10 Customer I/O Board	GDS1004-4002 -

5.3 ENHANCEMENT CARDS

Hardware	Order Code
SIGMA backplane for up to 4 enhancement cards	GDS1005-4001
HDLC card	GDS1006-4001
HDLC termination panel (fits on Customer I/O Board)	GDS1007-4001
HDLC ribbon cable - connection between enhancement card and termination panel	31V4200/10
Converter Diagnostics Fibre Optic to RS485 Board. Plugs into HDLC 'D' connector	-
FIP card	GDS1016-4001
FIP link a.c. earth connection assembly (2 per card required)	8992-4300
OPTOLINK card	GDS1193-6001

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5.4 POWER INTERFACE BOARDS

Hardware	Order Code
KIDSGROVE Power Interface Board - up to 6 delta modules, 3 on each bridge	
-	-
KIDSGROVE Power Interface Board - single delta modules.	
-	-
Type C: Provides 7 x 6 pulse outputs:	
Cyclos	GDS1198-6001
Single DC drive	GDS1198-6002
Dual IMDRIVE	GDS1198-6003
Max option build	GDS1198-6004
As 6001 with new desensitised ZCD	GDS1198-6005
As 6002 with new desensitised ZCD	GDS1198-6006
As 6003 with new desensitised ZCD	GDS1198-6007
As 6004 with new desensitised ZCD	GDS1198-6008
As 6005 with connectors	GDS1198-6009
As 6006 with connectors	GDS1198-6010
As 6007 with connectors	GDS1198-6011
As 6008 with connectors	GDS1198-6012
Type E: 2 x 6 pulse outputs: BDM2 compatible outputs	
BDM1 I/F (non preferred)	GDS1197-6001
BDM2 I/F	GDS1197-6002
W-L and Dual DC I/F	GDS1197-6003
As 6001 plus single phase field	GDS1197-6004
As -6003 - non preferred	GDS1197-6005
Common spare for BDM1/2 I/F	GDS1197-6006
All components	GDS1197-6007
Back Plate & hardware for PIB	GDS1197-6008
	GDS1197-6009
Type F - Used in GDM1 replacement	
Excludes encoder power supply	GDS1196-6001
Includes encoder power supply	GDS1196-6002
Type G: IPS Power Interface Board with fibre optic outputs use GDS1191 together with fibre optic SIM GDS1190	
Base board plus mounting plate	GDS1191-6001 to GDS1191-6003
Fibre optic daughter board for GDS1191	GDS1190-6001

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Hardware	Order Code
Type M: Used in 'M' reg replacement by SIGMA provides BDM and interface to M206 and M187	
Base board plus mounting plate	GDS1189-6001

5.5 BASIC I/O BOARDS

Description	Order Code
8 lamp/4 meter output	M72-60001
16 way digital input	M73-60001
8 way relay output	M75-60001,2
Fibre optic input panel	M76-60001-4
8 way digital output	M79-60001
16 way digital input	M80-60001

5.6 OTHER PERIPHERAL BOARDS

Description	Order Code
Encoder Interface Board	
Single encoder without terminating network	GDS1199-6001
Twin encoder without terminating network	GDS1199-6002
Single encoder with terminating network	GDS1199-6003
Twin encoder with terminating network	GDS1199-6004
Gating Power Supply	GDS1194-6001

5.7 POWER SUPPLY UNITS

Description	Order Code
Reduced size SIGMA power supply	
Type ZX200-647 - 110VAC in/ 48V dc out	GDS1192-6001
Type ZX200-648 - 48V dc in/ Normal out	GDS1192-6002
Type ZX200-649 - 1000, 240Vac in/ Normal out	GDS1192-6003

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6. CUSTOMER SUPPORT

If the user has any problems with the SIGMA Core Board, they should contact:

ALSTOM Power Conversion Ltd.
Customer Support Division
Boughton Road
Rugby
CV21 1BU
England

Telephone:- Rugby (01788) 563563 (International +44-1788-563563)
Fax:- Rugby (01788) 560767 (International +44-1788-560767)

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7. GLOSSARY

ANALOG TERMINATION PANEL	Interface for plant analogue inputs / outputs.
CSP	The PC based programming tool. Abbreviated to SIGMA Programmer in text. This is a top level .EXE program which invokes other programming tools.
CONTROL TASK	A collection of application software modules.
CUSTOMER I/O BOARD	Interface for plant digital inputs / outputs and serial links
DRIVE CONTROLLER	This comprises: SIGMA Controller Power Interface Board
DRIVE PACKAGE	This Comprises: SIGMA Controller Power Interface Board Power Stack
FAST TASK	A collection of application software modules
POWER BOARD	An interface between the Power Interface Board and certain sizes of Power Stack (e.g. thyristor bridge)
POWER INTERFACE BOARD	Interfaces between the SIGMA Core Board and the Power Stack
PWM	Pulse Width Modulated
SIGMA CONTROLLER	This comprises: SIGMA Core Board Customer I/O Board Analogue Termination Panel Switched Mode Power Supply
SIGMA CORE BOARD	The main printed circuit board containing the processor electronics
SIGMA CORE MOULDING	Comprises: SIGMA Core Board and Keypad

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IP7015114

8. INDEX

A

Access Level 4-29
Analog Termination Panel 1-10
Analogue I/O
  Main inputs 1-10
  Outputs 1-11
  Summary 1-4
Analogue Inputs
  I/O processor inputs 1-10
Analogue Termination Panel 1-4
Application Software
  Summary 1-4
Attributes 4-29

B

Background Loop 2-3
Backup of Programs 2-9
Basic I/O
  Additional I/O 1-7
  Configuration 1-8
  Customer I/O inputs 1-6
  Error codes 4-22
  Outputs 1-7
  Update Rate 1-8
BATTERY
  Battery type 1-25
  Replacement Procedure: 1-25
Battery Supply 2-8
Baud Rate 1-13, 1-14
BOOT UP EEPROM 2-1
Boot Up Faults 4-15

C

Calendar Clock 1-24
Code Area Corruption 4-18
Commissioning Mode 2-7
CONFIG T33 ..... 1-15, 1-16
Control Task 3-1
CSP 3-1, 4-13
Customer I/O Board 1-6

D

Data Tables
  Addresses 4-27
  Attributes 4-28
  Initialisation 2-2
  L tables 4-27
  When Updated 4-31
DEF TABLE
  limits 3-5
  Scaling 3-5
  Setting Attributes 4-29
  Text String 3-5
  Units 3-6
Digital I/O
  Input Data Tables 4-32
  Inputs 1-6
  Outputs 1-6
  Summary 1-4
  When Inputs Read 2-3
  When Outputs Written 2-3
Digital Outputs
  Basic I/O 4-34
  Short-circuit Protected 1-7
Downloading New Firmware 2-14
Drive ID 2-5

E

Early Power Fail Warning 2-8
Encoder
  Connections 1-9
  Driver module 1-8
  Inputs 1-8
  Summary 1-4
Encoder Interface Board 1-9
Enhancement Card
  Configuration 1-22
  Presence 1-22
Enhancement Interface
  Summary 1-4
ESP 1-4, 1-13
  Programming Messages 1-20
  Table Exchange 1-17
ESP Configuration 3-6
Execution Cycle 2-2

F

Fast Digital Inputs 1-6
Fast Task 3-1
Fast Task Failure 4-20
Fault Display 4-6
FIP 1-4, 1-12
Firmware
  Reference 4-10
Firmware Database 2-1
FLASH
  Error Codes 4-24
FLASH Programming 2-9

G

GDMMOD 3-7
General Fault Handler 4-23

H

Halt/Run 2-3, 2-5
HDLC 1-4

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HDLC Configuration 3-6
HDLC Serial Comms Card 1-4
HEADER
Drive Reference 3-2
Drive Title 3-2
Fast Task 3-2
firmware Reference 3-2
Issue Number 3-2

I

I/O Processor 1-8
Analogue inputs 1-10
error codes 4-24
Initialisation 2-1

J

J/K Table Allocation 1-17

K

Keypad
Display 4-6
LEDs 4-2
Link Failure 4-5
Menu 4-2
Status Montoring 4-36
Variable Monitor & Edit 4-3
Keypad Edit 4-8
Keypad Local Control 4-33
Keypad Messages 4-7
Keypad Mode 4-9
Keypad Monitor 4-8

L

L tables 4-27
Ladder Instructions 3-7
Ladder Program 1-4
Purpose 3-6
Language 3-3
Languages 4-10
LED Display 4-15
LEDs
Core Board 4-15
Limits 3-5
Link attribute 3-4
Links Program 1-4
Example 3-4
Function 3-4
Rules 3-4

M

Memory Checks 2-1
MODBUS 1-4, 1-15, 1-16
Registers 1-19
Summary 1-18
Monitoring
Keypad LEDs 4-2
via keypad 4-5, 4-8

N

Network card 1-4

O

OIS 3-3
Display via Keypad 4-10
Error Codes 4-25
Firmware 2-1
Hardware OIS 1-23
OPTOBUS 1-4
Oscilloscope Outputs 4-9, 4-37
OVERVIEW 3-1

P

Password 4-7, 4-30
Power Interface Board
Analogue Inputs 1-10
Summary 1-4
Power Up 2-1
Pulse Enable signal 2-5

R

RAM 4-20
RAM Failure 4-20

S

Scaling 3-5
Scan Time 2-4
Error Conditions 4-24
Scope Outputs 1-11, 4-12, 4-37
Selection via Keypad 4-12
via Data Tables 4-37
Serial Links
Baud Rate Selection 1-13, 1-14
Configuration 3-6
Execution Point 2-4
Link 0 1-13
Link 0 Configuration 1-13
Link 1 1-15
Link 2 1-15
Statistics 1-20
Summary 1-4
SIGMA Layout 1-1
Software Key 4-39
Special Functions 3-8
Stack Overflow 4-19
Supply Checks
Range 4-35
Range Check 2-8
Watchdog Error Codes 4-23
When Performed 2-3
Symbol Table Corruption 4-19

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IP7015116

System Status Bits 4-34

T

Table Descriptions 3-5
Temperature Monitoring 4-35
Test Facility 2-7
Text Comments 3-5
Time 1-24
Tributary Address 1-13

U

User Program
  Execution Point 2-3
USERPROG 3-4

W

Warning Messages 4-14
Watchdog 2-12
  Error Codes After Power Loss 4-26
  Safety Issues 2-12
Watchdog Errors
  Basic I/O Failure 4-22
  Code Area Corruption 4-18
  Code General Fault Handler 4-23
  Fast Task Failure 4-20
  Flash programming failure 4-24
  I/O Processor Failure 4-24
  OIS Incorrect 4-25
  RAM Failure 4-20
  Slow task Scanning Failure 4-24
  Stack Overflow 4-19
  Supply Check Failure 4-23
  Symbol Table Corruption 4-19
  Watchdog Self Test Failure 4-21
  XILINX DPR Failure 4-21
Watchdog Relay
  Output 1-7
Watchdog Self Test Failure 4-21

X

XILINX 4-20, 4-21
XILINX RAM Failure 4-21

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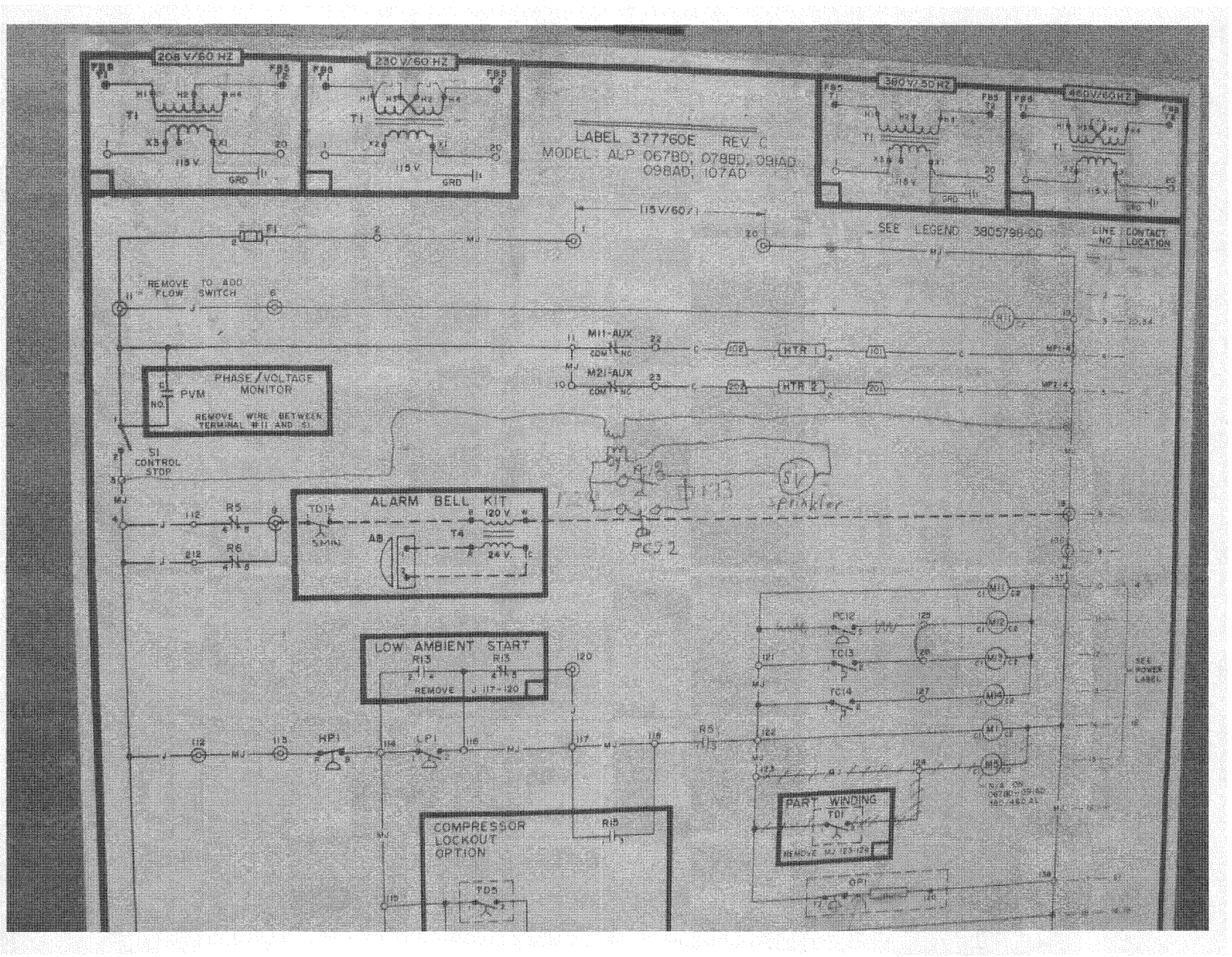
Induced Draft Fan Motors

DATA

Frame size	B2611S90
Motor Type	Synchronous
Enclosure	WPII
Horsepower	7415/4596
Voltage	3876/3876
Power factor	0.90
Full load amperes	472/538
Hertz	63.6/53.93
Phase	6/3
Exciter field amperes	44
Service factor	1.0
Application	AFAC Fan Drive
Load torque curve	9255-DE 1001
Load wk^2 $lb\text{-}ft^2$	347,700
Motor wk^2 $lb\text{-}ft^2$	35,000
Poles	8
Speed	954/809
Rotation	4 motors CW, 4 motors CCW
Insulation class	F
Ambient	45 C
Altitude	4676 feet
Temperature rise	75 C
Breakdown/pull-out torque	200%
Sound level	80 dBA @ 1 meter
Manufacturer	Westinghouse
Accessories	Differential current transformers (800:5) Motor space heater 4500 watts Exciter space heater 5000 watt Stator RTD's six 10 ohm @ 25 C copper Bearing TC Type E

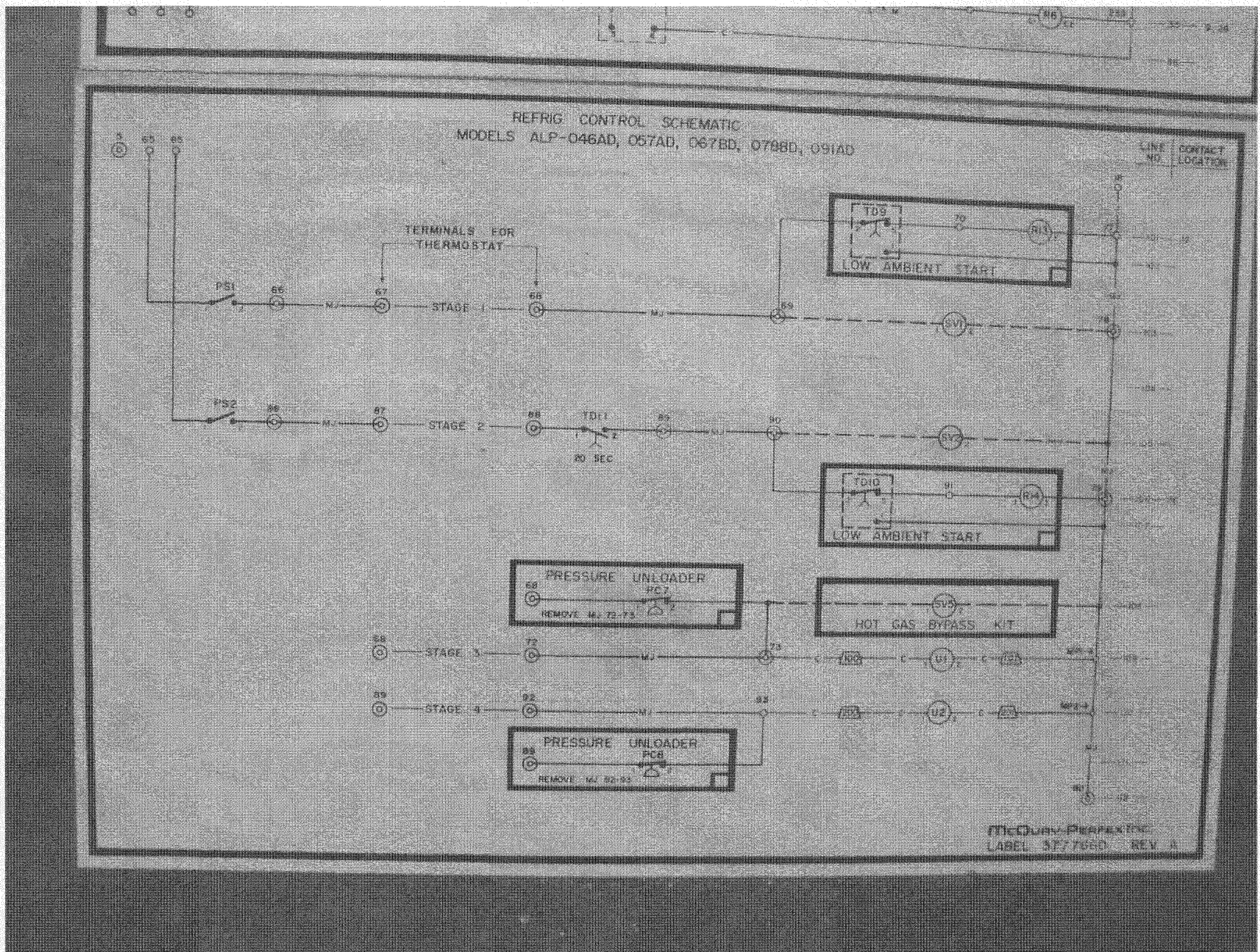
				Ch 1 Channel				Ch 2 Channel			
I/O	Address	New Description	TB	Current Termination	Cable #	Color	Destination	Current Termination	Cable #	Color	Destination
Sigma Digital Inputs	A1.0	Off	5TB	B2CX	2CCE-K2127 B12	BK	Modicon	B2CX	2CCE-K2128 B18	BK	Modicon
				C1811		Y		C1811		Y	
	A1.1	Turning Gear		B2CX		Com		B2CX		Com	
				C1812		BL		C1812		BL	
	A1.2	Run		B2CX		Com		B2CX		Com	
				C1813		O		C1813		O	
	A1.3	Start	5TB	B2CX		Com		B2CX		Com	
				C1823		BR		C1823		BR	
	A1.4	Output Disconect Closed	5TB	B2CX	2CCE-K2127 B07	BK	Output Disconnect	B2CX	2CCE-K2128 B07	BK	Output Disconnect
				C1720		R		C1720		R	
			EXX-V	C2X	2CCE-K2127 B06	BR	Output Disconnect	C2X	2CCE-K2128 B06	BR	Output Disconnect
				C213		R-BK		C213		R-BK	
	A1.5	Reactor Fan Fail Alarm OK	5TB	B2CX	2CCE-K2127 B01	BK	Reactor Cabinet	B2CX	2CCE-K2128 B01	BK	Reactor Cabinet
				C1714		R		C1714		R	
	A1.6	Reactor Temp Trip OK	5TB	C1715		BL		C1715		BL	
				B2CX		Com		B2CX		Com	
				C1716		O		C1716		O	
	A1.7	Slave Input (From Other Ch's Master O/P)			NEW CABLE		Ch 2 Regualtor		NEW CABLE		Ch 1 Regualtor
	A2.0	Other Ch Running	5TB	C1725	2CCE-K2128 B25	R	Ch 2 Regualtor	C1725	2CCE-K2128 B19	R	Ch 1 Regualtor
				B2CX		BK		B2CX		BK	
	A32.1	Position Sensor 1			NEW CABLE				NEW CABLE		
	A32.2	Position Sensor 2									
	A32.3	Position Sensor 3									
	A32.7	Pulse Release Permissive			Internal				Internal		
Sigma Digital Outputs	B1.8	Drive Healthy (DHR)	EXX V	C1930	2CCE-K2127 B14	BR	Modicon	C1930	2CCE-K2128 B14	BR	Modicon
				C1931		Com		C1931		Com	
	B1.9	Drive Alarm (DAR)	EXX V	C1934	2CCE-K2127 B08	BK	Annunciator	C1934	2CCE-K2128 B26	BK	Annunciator
				C1935		R-Com		C1935		R-Com	
	B1.10	I/P Bkr Trip (IBT)	A20TB	C2011	2CCE-K2127 B02	BK-1	Bkr Trip Pnl (Module)	C2011	2CCE-K2128 B02	BK-1	Bkr Trip Pnl (Module)
				C2012		W-1		C2012		W-1	
			EXX V	C1928	2CCE-K2127 B14	BK	Modicon	C1928	2CCE-K2128 B14	Y	Modicon
				C1929		R		C1929		Com	
			EXX V	C1936	2CCE-K2127 B08	BL	Annunciator	C1936	2CCE-K2128 B26	BL	Annunciator
				C1937		Com		C1937		Com	
	B1.11	Close Exc (FCC)	Internal								
	B1.13	Close Output Disconnect	EXX V	B7A13	2CCE-K2127 B06	BL	Output Disconnect	B7A13	2CCE-K2128 B06	BL	Output Disconnect
				B7A14		O		B7A14		O	
	B1.14	Spare									
	B1.15	Spare									
	B3.0	Zero Speed	EXX V	C1942	2CCE-K2128 B23	BK	D Channel	C1942	2CCE-K2128 B14	O	Modicon
									2CCE-K2128 B23	BK	D Channel
				C1943		R-Com	D Channel	C1943	2CCE-K2128 B23	R-Com	D Channel
	B3.1	Min Speed		C1944		BL	D Channel	C1944	2CCE-K2128 B14	BL	Modicon
									2CCE-K2128 B23	BL	D Channel
								C1945	2CCE-K2128 B14	Com	Modicon
	B3.2	Turning Gear Speed		C1954		Y	D Channel	C1954	2CCE-K2128 B14	R	Modicon
									2CCE-K2128 B23	Y	D Channel
								C1955	2CCE-K2128 B14	BK-Com	Modicon
	B3.3	Speed Reference Lost		C1946	2CCE-K2127 B09	BK	Bailey	C1946	2CCE-K2128 B24	BK	Bailey
				C1947		R		C1947	2CCE-K2128 B24	R	
	B3.4	Running Speed									
	B3.5	Master-Slave Output (To Other Ch's Slave I/P)			NEW CABLE		Ch 2 Regualtor		NEW CABLE		Ch 1 Regualtor
	B3.6	This Ch Running	EXX V	MP1-8	2CCE-K2128 B19	BK	Ch 2 Regualtor	MP1-8	2CCE-K2128 B25	BK	Ch 1 Regualtor
				MP1-9		R		MP1-9		R	
	B3.7	Spare									
Sigma Analogue Inputs	C14	Customer Speed Ref	A20TB	C917	2CCE-K2127 B10	BK	Bailey Boiler Control	C917	2CCE-K2128 B22	BK	Bailey Boiler Control
				C918		W		C918		W	
	C15	Torque Ref Input	ATB19	C3317	2CCE-K2128 B21	W-1	Ch 2 Regulator	C3317	2CCE-K2128 B21	W-2	Ch 1 Regulator
				C3318		BK-1		C3318		BK-2	
	C16	Spare from other channel									
	C17	Spare									
Sigma Analogue Outputs	D0	Exciter Reference									
	D1	Torque Ref Output	ATB19	C3313	2CCE-K2128 B21	W-2	Ch 2 Regulator	C3313	2CCE-K2128 B21	W-1	Ch 1 Regulator
				C3314		BK-2		C3314		BK-1	
	D2	Spare to other channel									
	D3	Spare									
	D4	Motor Speed						C33B11	2CCE-K2128 B09		Bailey Boiler Control
								C33B12			
			EXX H	C3315	2CCE-K2128 B08	BK-1	Ch 2 Regulator	MP1-5	2CCE-K2128 B08	BK-1	Ch 1 Regulator
				C3316		W-1		MP1-14		W-1	
				C3311		BK-2		MP11-5		BK-2	
				C3312		W-2		MP11-14		W-2	
	D5	Motor Voltage	3TB	C3323	2CCE-K2104 C03	BK-1	Metering Controll Panel (MCP)	C3323	2CCE-K2104 C04	BK-1	Metering Controll Panel (MCP)
				C3324		W-1		C3324		W-1	
	D6	Motor Current	3TB	C911		BK-2		C911		BK-2	
				C912		W-2		C912		W-2	
	D7	Spare									


208 V/60 HZ
230 V/60 HZ
380 V/50 HZ
460 V/60 HZ
LABEL 377760E REV C
MODEL ALP 067BD, 078BD, 091AD
098AD, 107AD
115 V/60/1
SEE LEGEND 3805798-60
LINE CONTACT
NO. LOCATION
REMOVE TO ADD
FLOW SWITCH
PHASE/VOLTAGE
MONITOR
PVM
REMOVE WIRE BETWEEN
TERMINAL #11 AND S1
S1
CONTROL
STOP
ALARM BELL KIT
120 V
24 V
LOW AMBIENT START
REMOVE
COMPRESSOR
LOCKOUT
OPTION
PART WINDING
REMOVE
SEE
POWER
LABEL

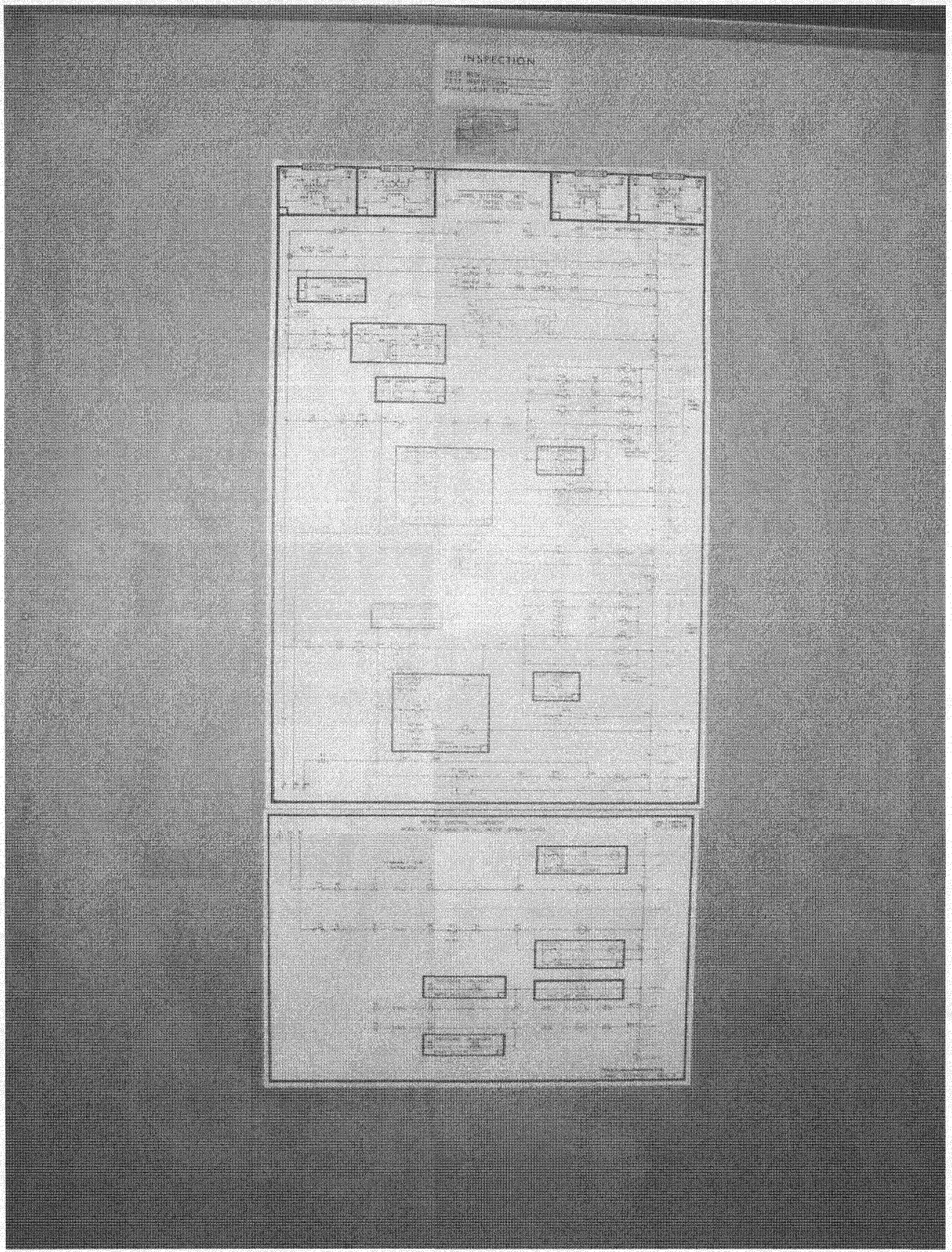
IP7015120

LOW AMBIENT START
COMPRESSOR LOCKOUT OPTION
PART WINDING
M1-AUX
M2-AUX

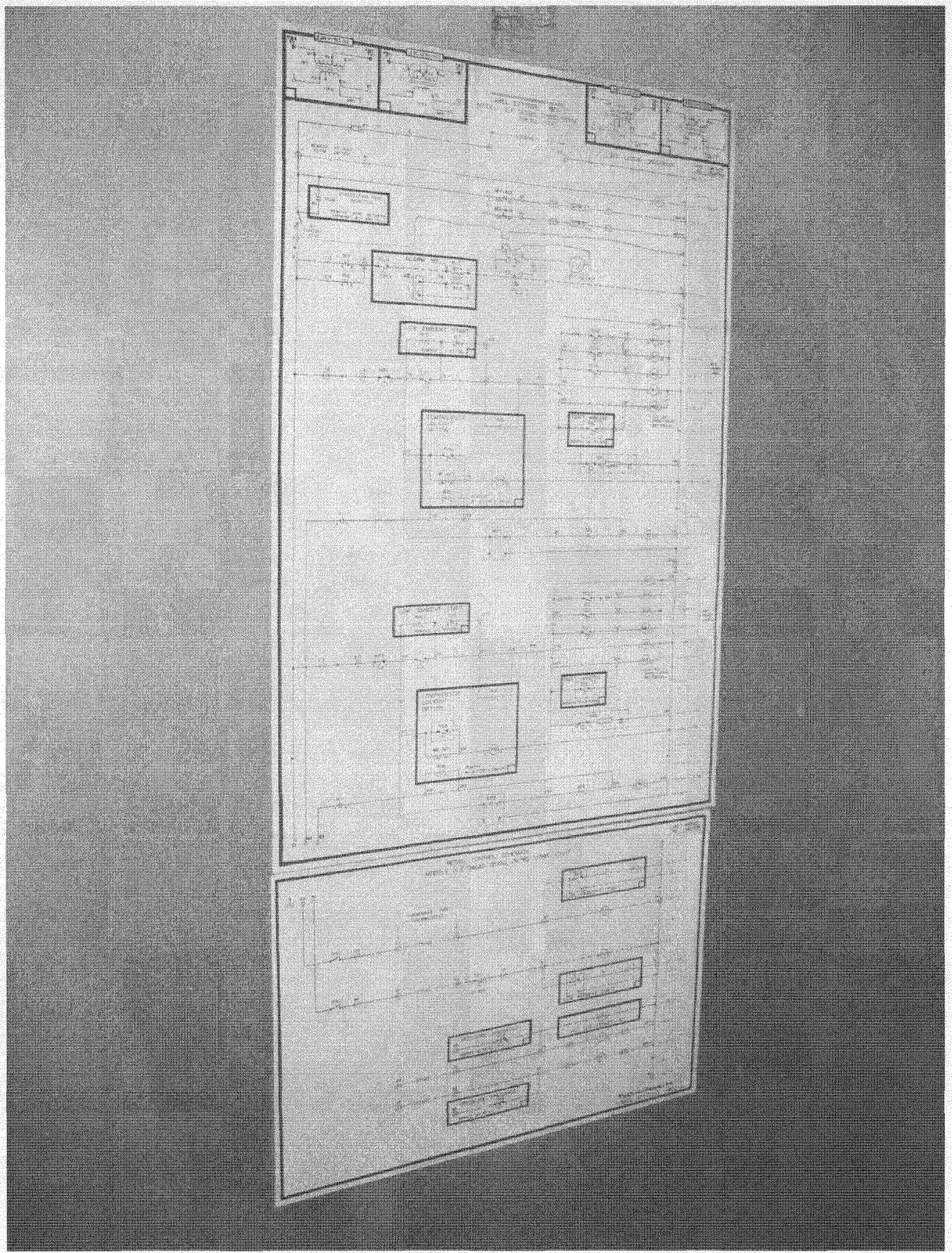
IP7015121


REFRIG CONTROL SCHEMATIC
MODELS ALP-046AD, 057AD, 067BD, 078BD, 091AD
LINE NO.
CONTACT LOCATION
TERMINALS FOR THERMOSTAT
PS1
PS2
STAGE 1
STAGE 2
STAGE 3
STAGE 4
TD11
20 SEC
TD9
LOW AMBIENT START
TD10
LOW AMBIENT START
PRESSURE UNLOADER
PC7
REMOVE MJ 72-73
HOT GAS BYPASS KIT
PRESSURE UNLOADER
PC8
REMOVE MJ 82-93
McQuay-Perfex Inc.
LABEL 3777660 REV A

IP7015122



IP7015123



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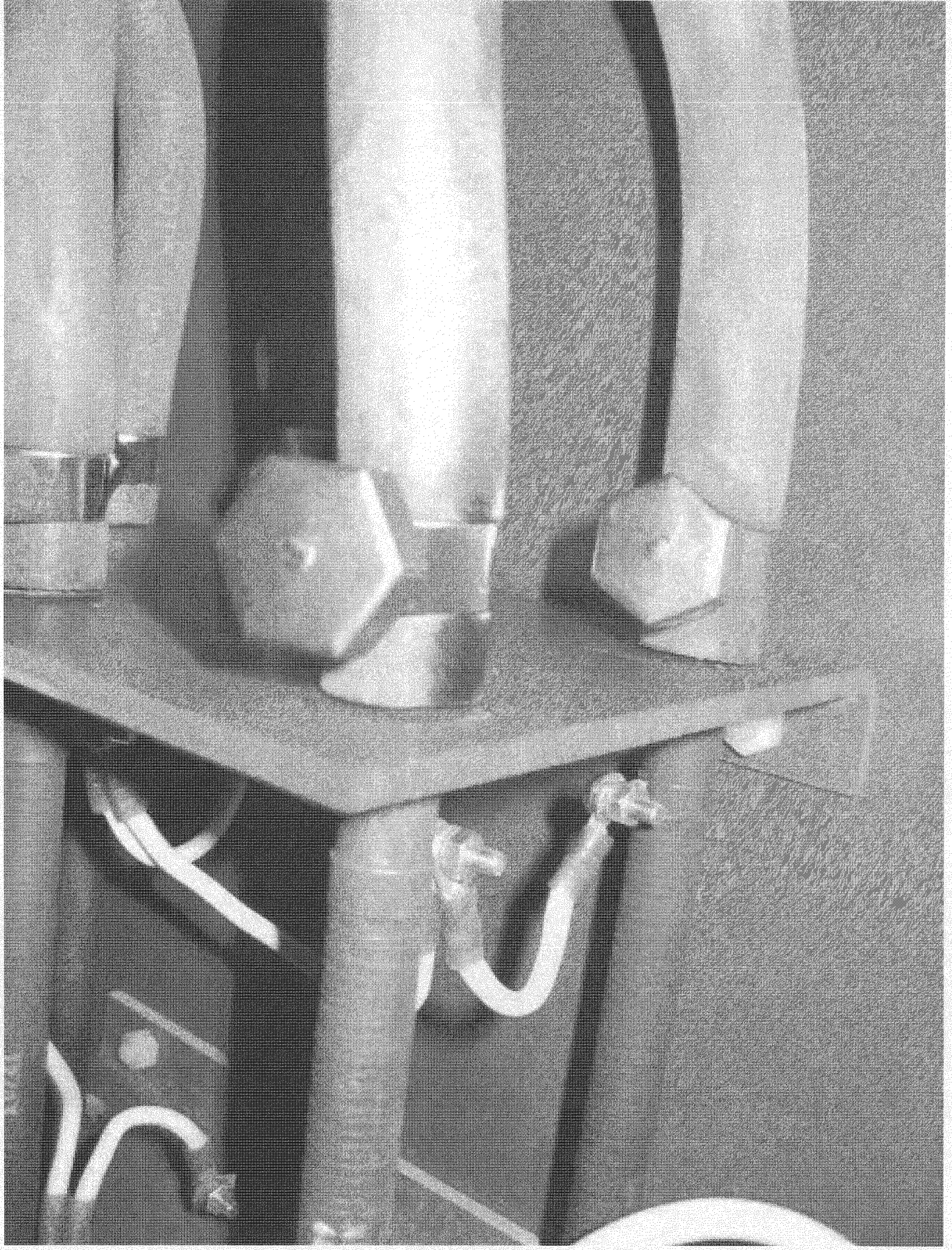
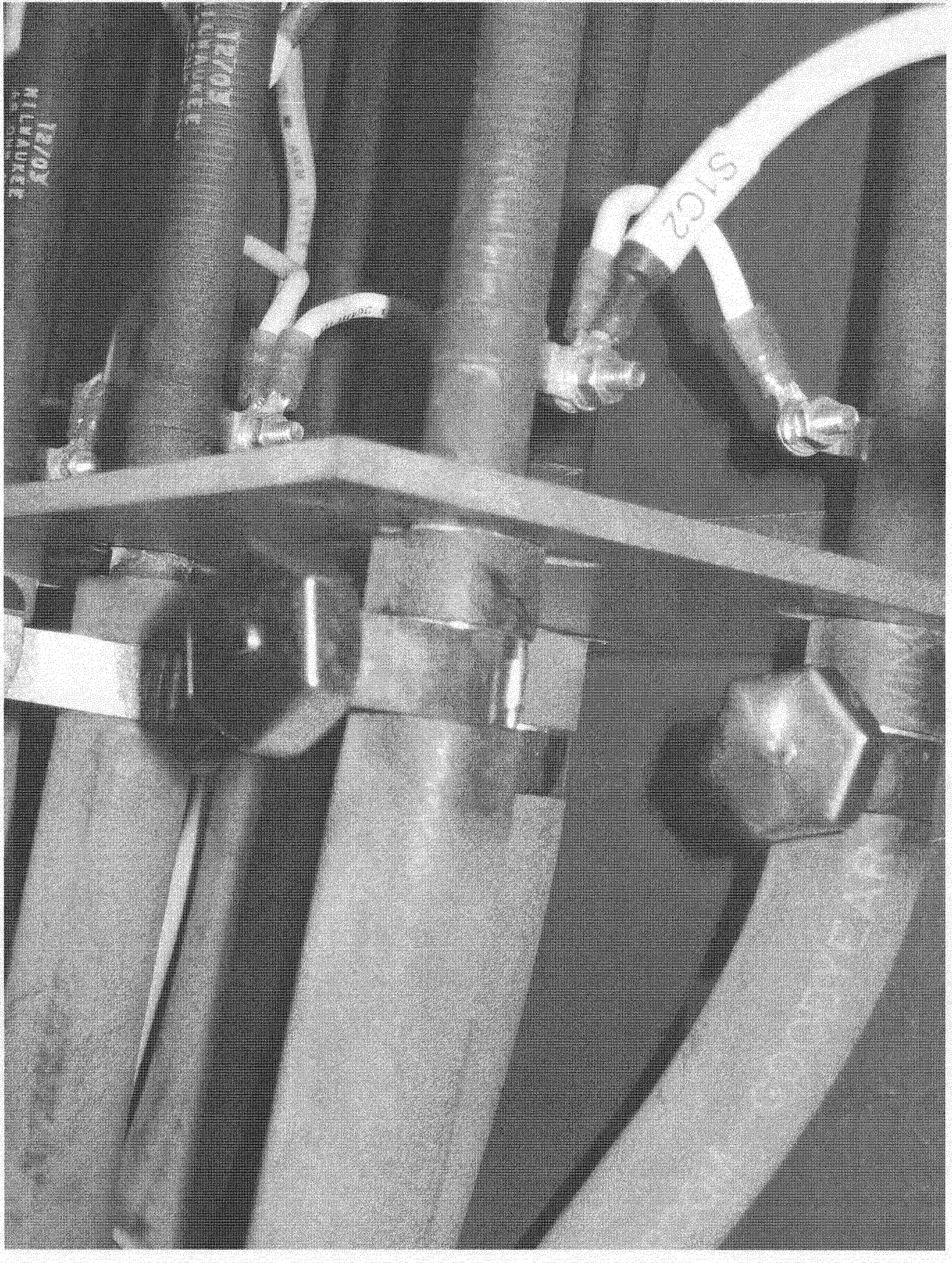


IP7015125

IP7015126

IP7015127



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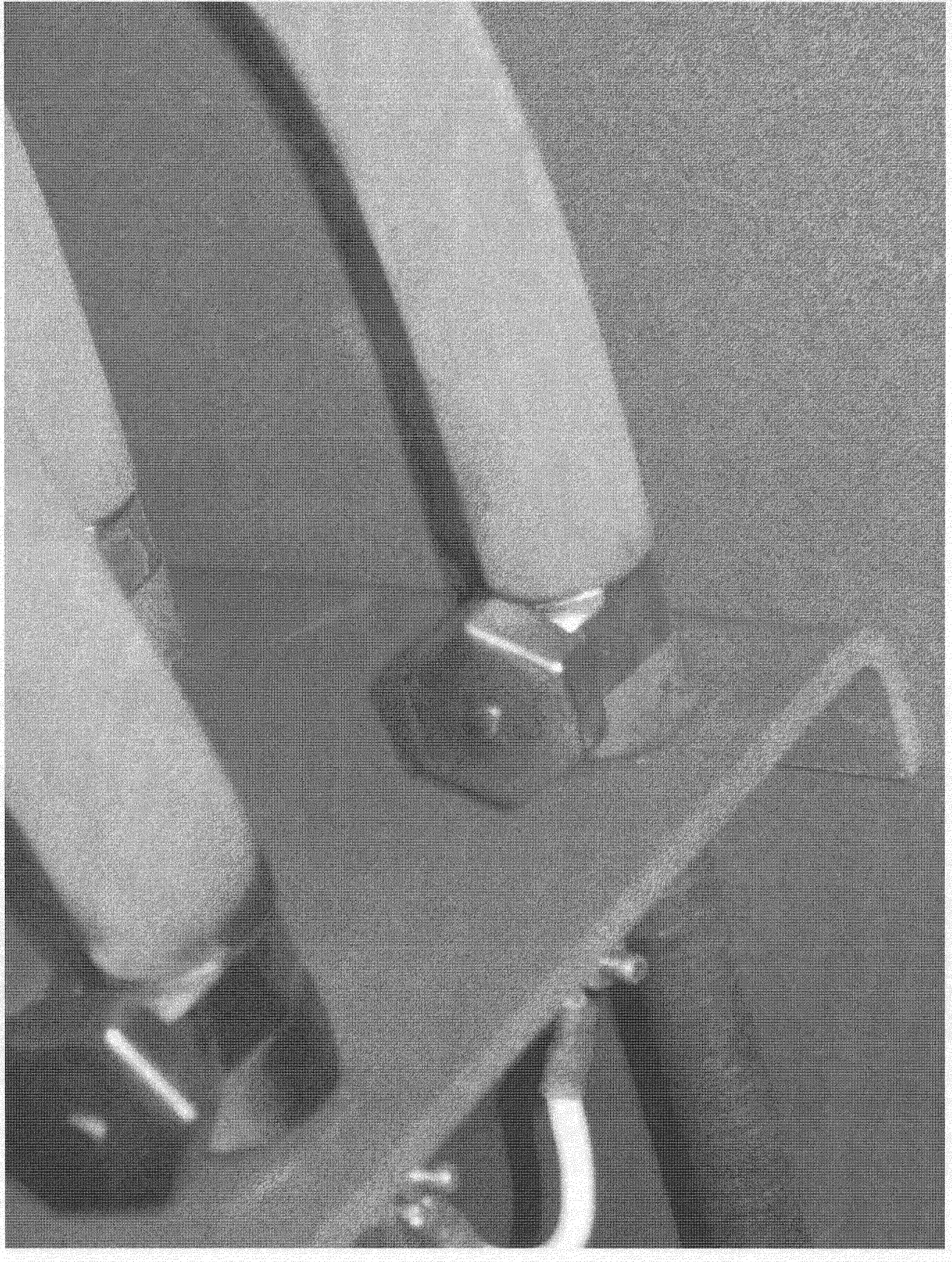
IP7015129



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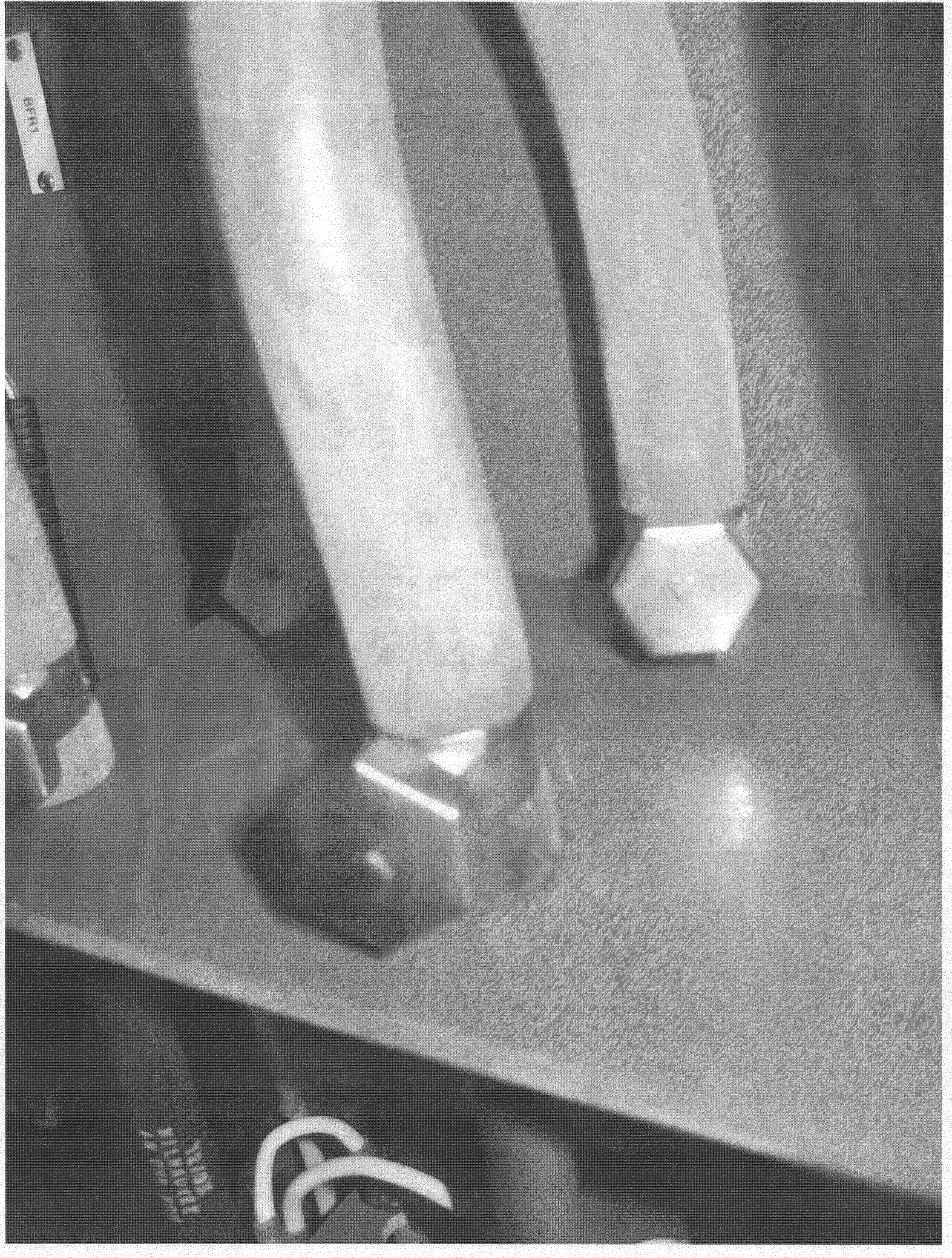

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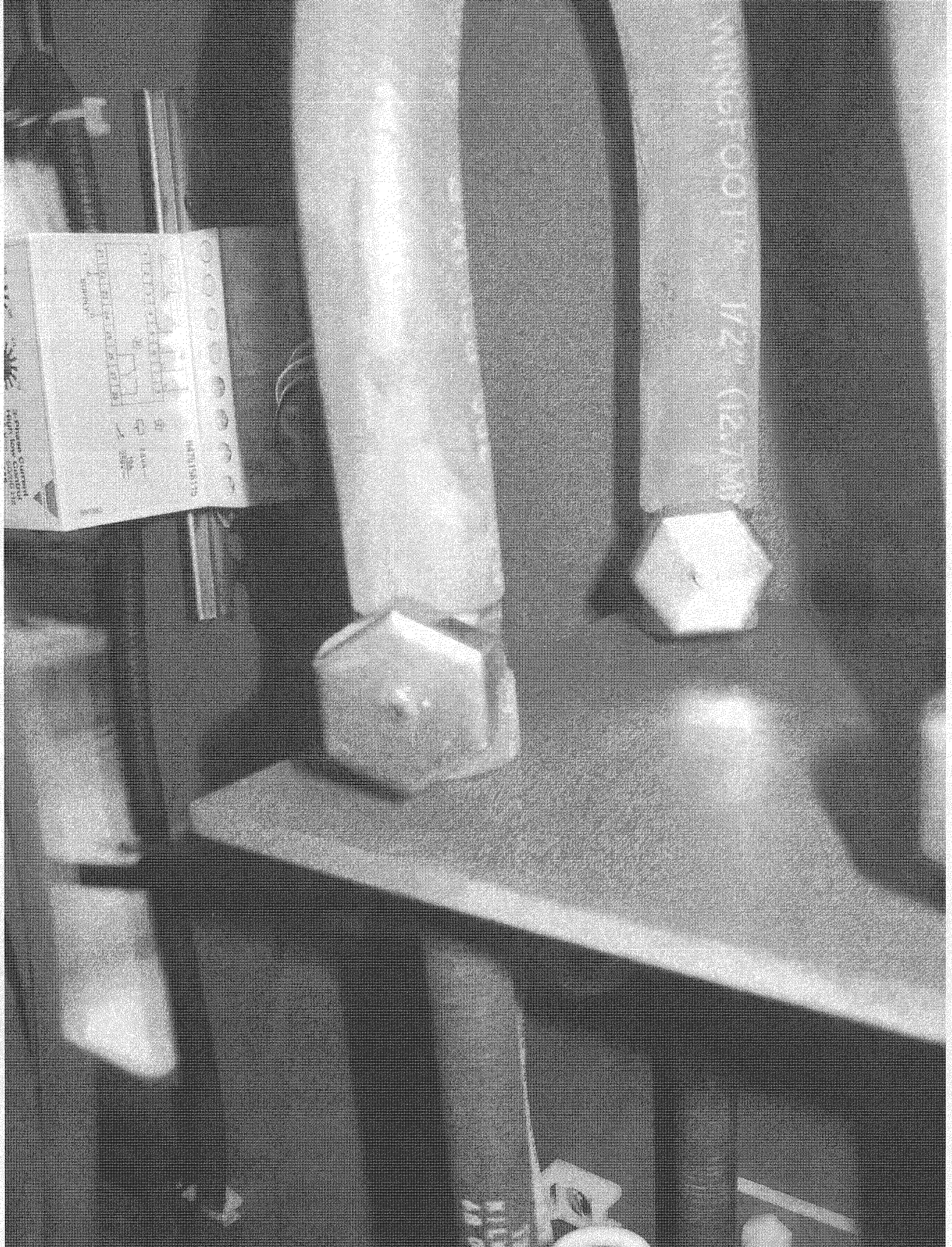

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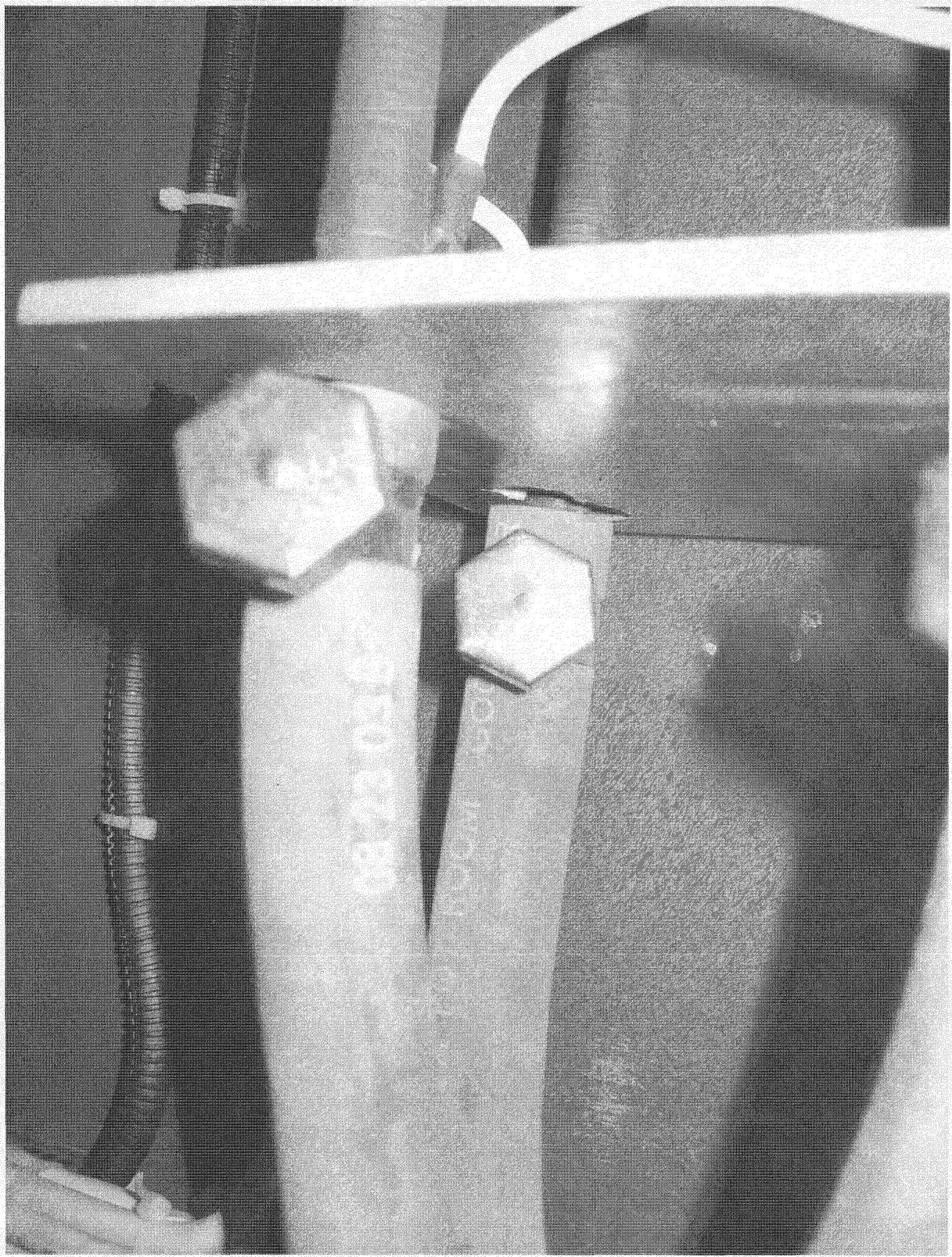

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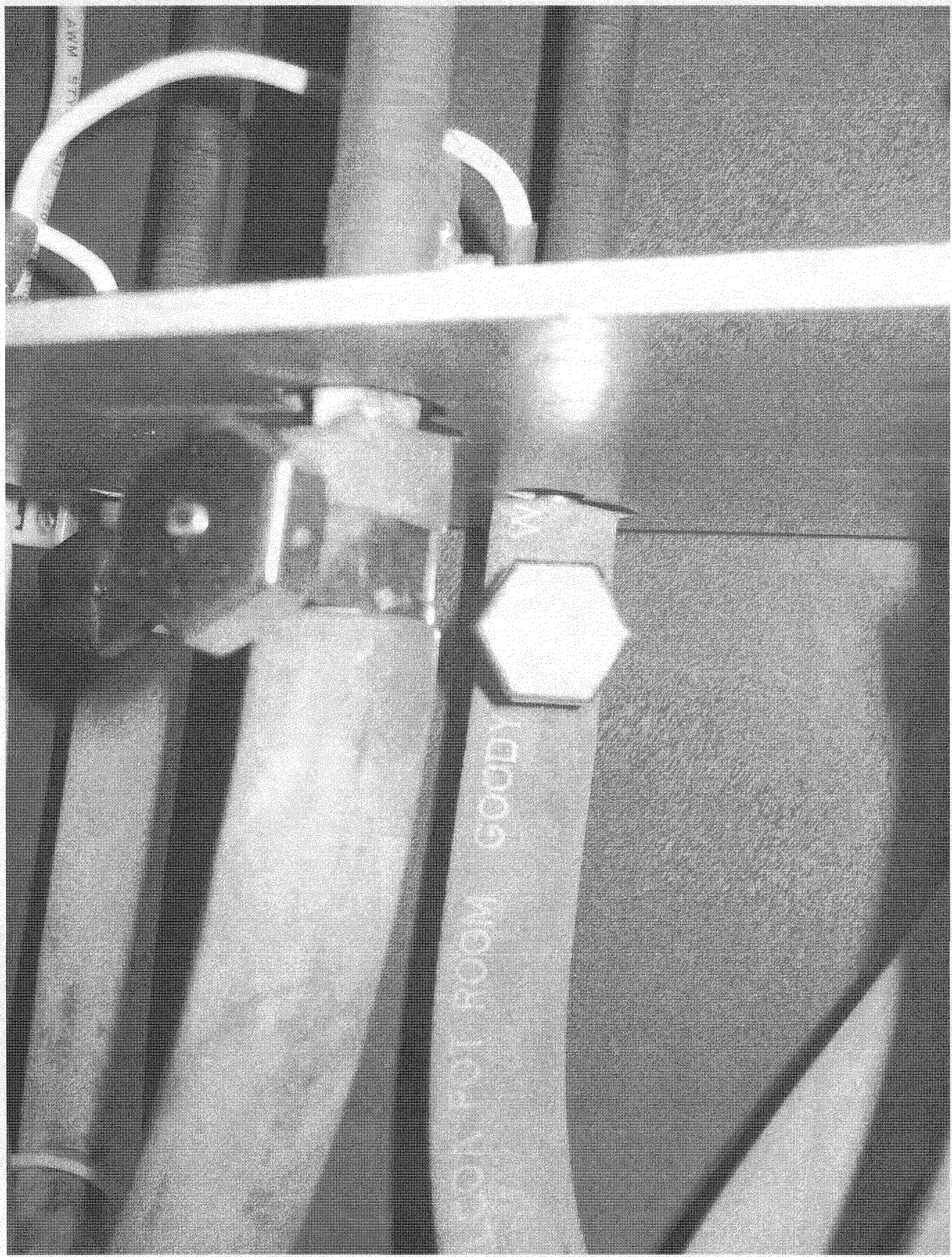

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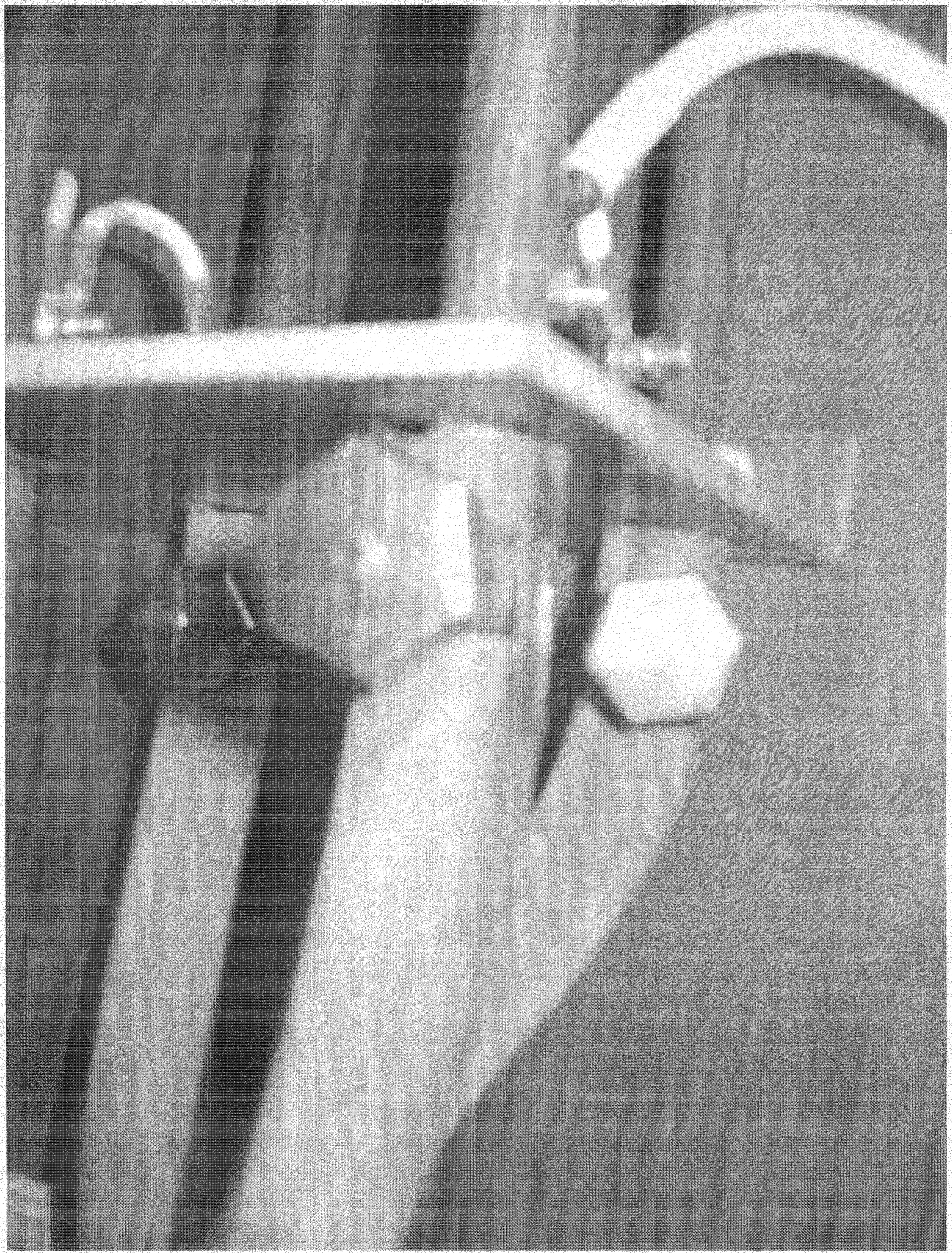

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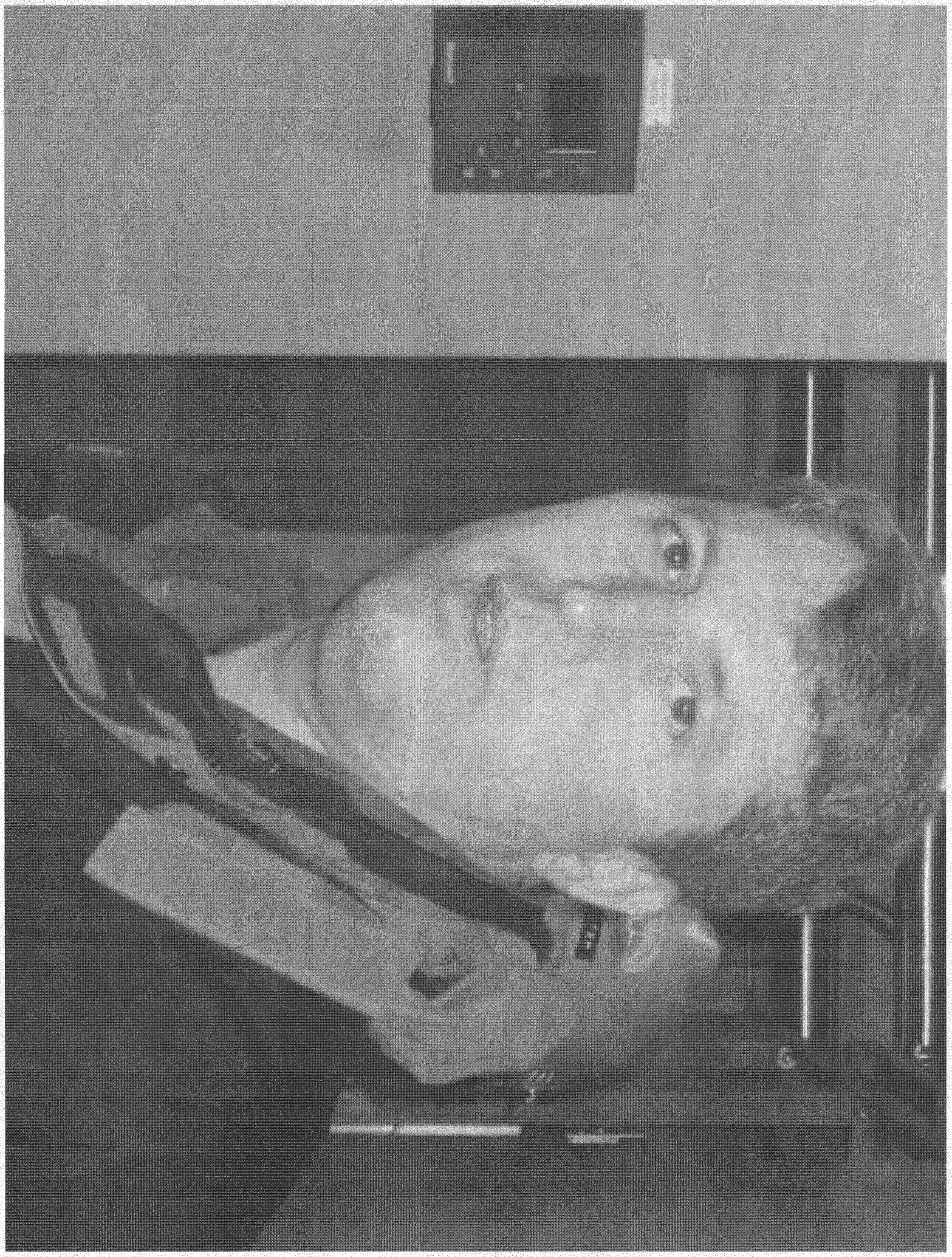


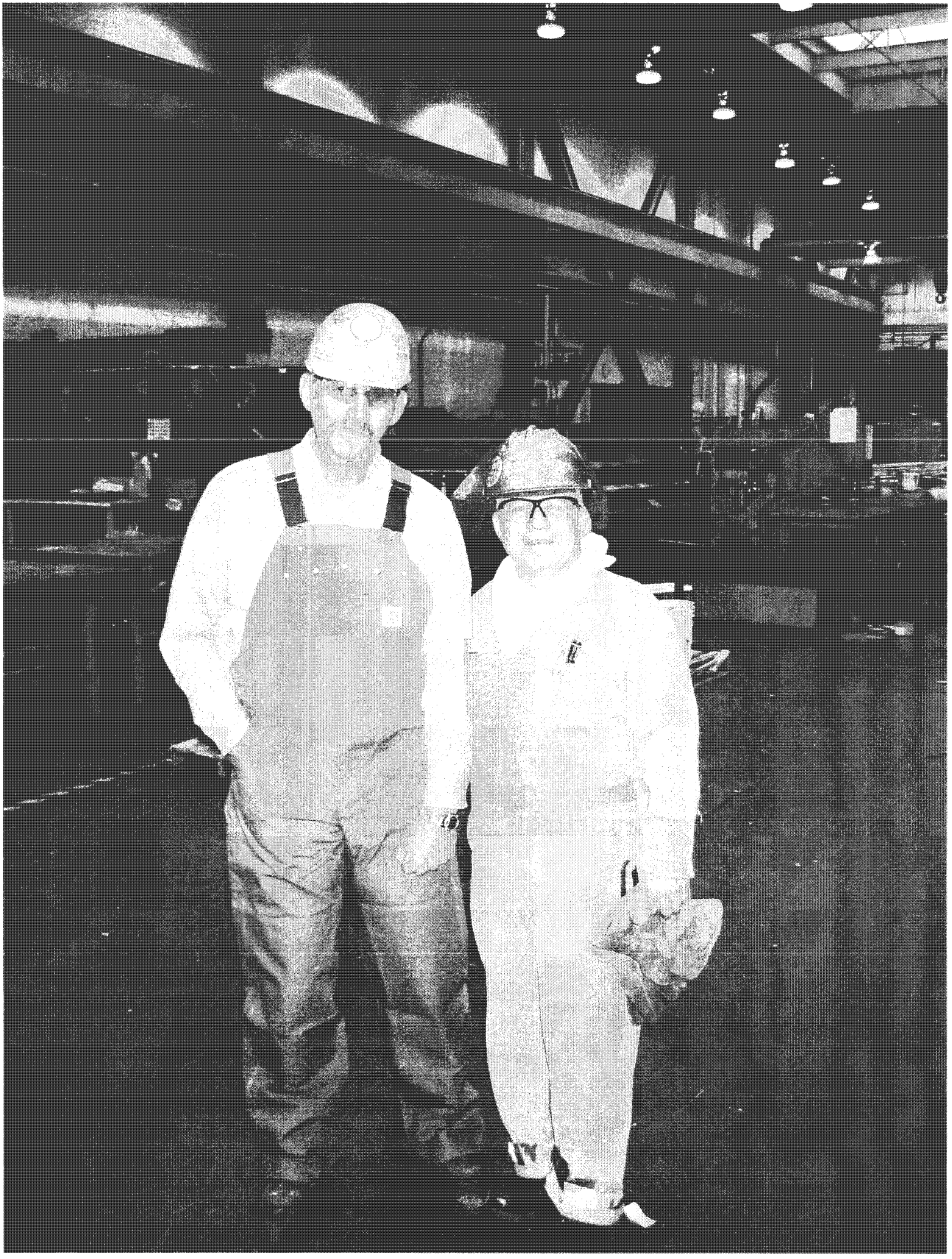
IP7015136

The following is used to establish LCI drive (only) efficiency using IEEE 995 methods
The data used is for the IPSC job which uses a dual channel drive system so losses are doubled
Refer to the IEEE 995 standard for definitions, section references (e.g. 5.3.5.2) and supporting explanations.

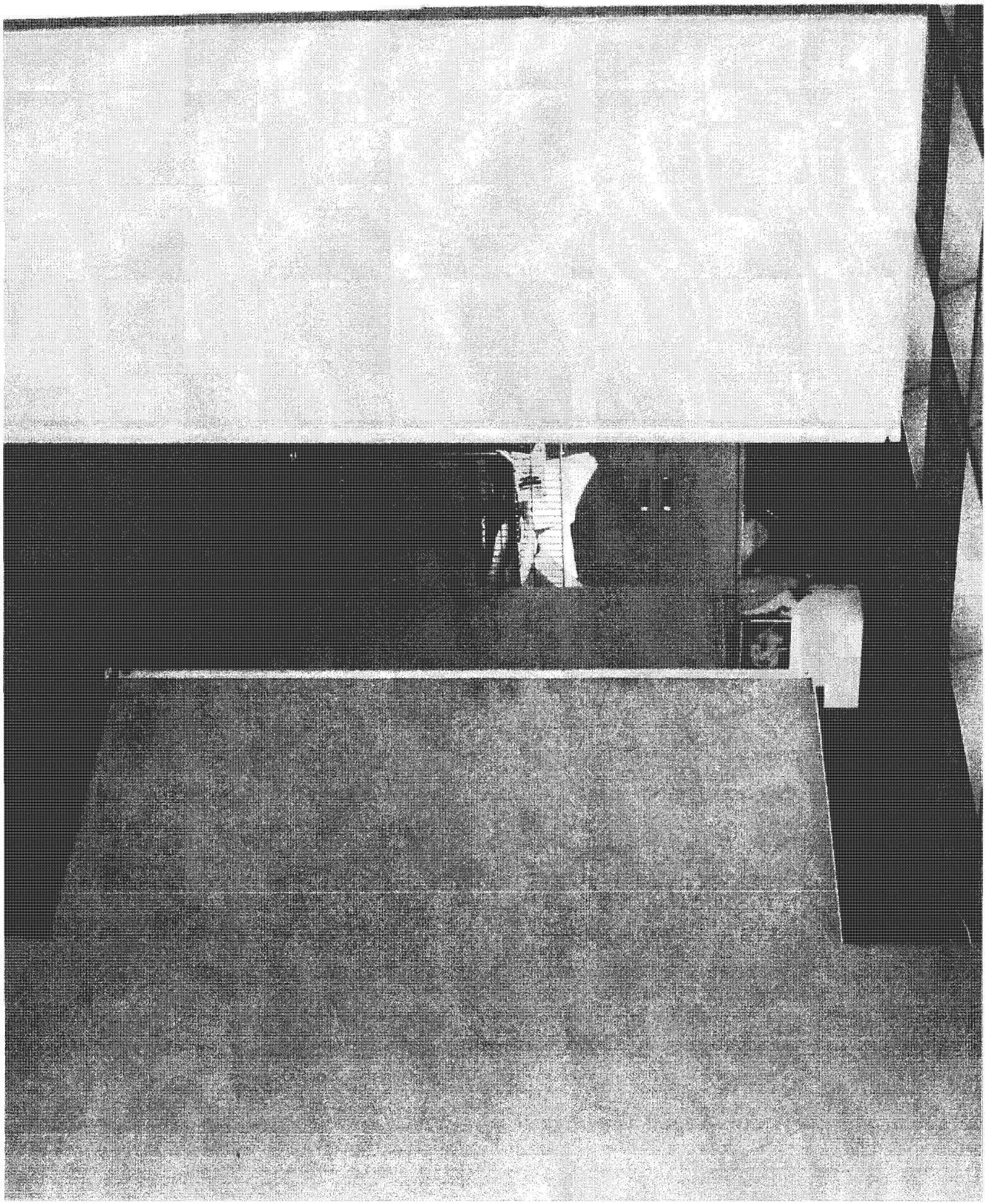
A number of different speed and set up conditions are considered: -

1. The 100% speed and load contract evaluation point
2. The 80% speed, 50% load, contract evaluation point
3. The 100% load point after the proposed adjustments to motor and supply voltage for PF improvements
4. The 100% load point after adjustment to motor voltage of 4,160 V

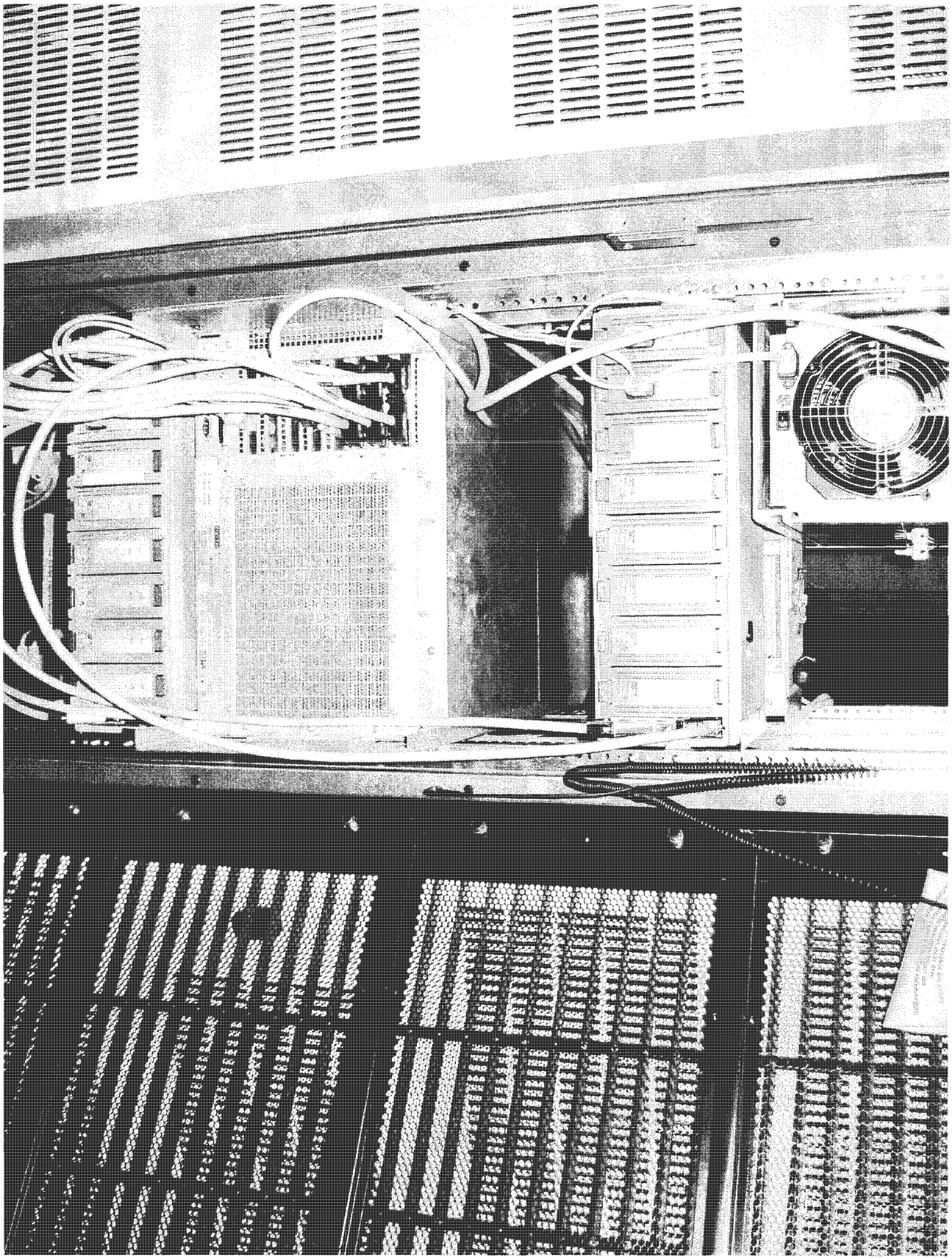
	1	2	3	4	
General Conditions	**100%**	**80%**	**100%**	**100%**	
Rating (Hp)	7415	3796	7415	7415	
Speed (RPM)	954	763.2	954	954	
Motor I (Amps)	472	256	450	440	
Motor E (Volts)	3876	3657	4070	4160	
Motor fm (Hz)	63.6	50.88	63.6	63.6	
Motor PF (Fpp)	0.9	0.9	0.9	0.9	
Supply I (Amps)	472	256	450	440	
Supply Ell (Volts)	4031	4031	3839	3933	
Supply fs (Hz)	60	60	60	60	
Section 5.3.5.2	**Thyristor loss by method 2 (published data)**				
DC Current Idc (Amps) =	605.36	328.48	576.54	564.04	[I x ¶/2.4495]
SCR Volt drop (Vscr Volts) =	1.2534	1.0803	1.2353	1.2275	[Vscr = 0.875 + Idc/1600] (Published data for type C702 SCR)
One SCR Loss (Watts) =	758.7	354.9	712.2	692.4	[Vscr x Idc]
Channel SCR loss (Watts) =	15175	7097	14244	13847	(4 arms of 5 SCR's each)
Total SCR Loss (Watts) =	30349	14194	28489	27695	(2 channels)
x by 1.05 (Total SCR Watts loss) =	31867	14904	29913	29079	(5% allowance made for switching losses)
Section 5.3.5.3	**Power Circuit Connectors**				
Bus loop resistance (Rbus Ohms) =	0.00125	0.00125	0.00125	0.00125	(value taken from measured data plus correction to 90°C)
Loss per channel (Watts) =	458	135	415	398	[Idc² x Rbus]
Total loss (Watts) =	916	270	831	795	(2 channels)
Section 5.3.5.4	**RC Filters and Snubbers**				
Cy (uF) =	0.5	0.5	0.5	0.5	
Ry (Ohms) =	102	102	102	102	
Cs (uF) =	1	1	1	1	
Rs (Ohms) =	24	24	24	24	
Re (Ohms) =	20000	20000	20000	20000	
n (number of SCR's per arm)	5	5	5	5	
Alpha supply (Øs degrees) =	29.06	34.45	15.48	15.92	[ArcCos(E x Fpp/0.99 x Ell)]
Alpha machine (Øm degrees) =	31.24	31.24	31.24	31.24	[ArcCos(Fpp x 0.95)]
Surge circuit supply side					
Plf (Watts) =	59	59	53	56	[(2¶)² x fs² x Cy² x Ell² x Ry]
Phf (Watts) =	690	936	189	209	[3 x fs x Cy x Ell² x (Sin² Øs + Sin² (Øs + μ))]
(μ = 0° per 995 std)					
Total for supply surge circuits (Watts) =	1498	1989	485	531	[2 x (Plf + Phf)]
Surge circuit machine side					
Plf (Watts) =	61	35	67	70	[(2¶)² x fm² x Cy² x E² x Ry]
Phf (Watts) =	771	549	850	888	[3 x fm x Cy x E² x (Sin² Øm + Sin² (Øm + μ))]
(μ = 0° per 995 std)					
Adjustment for x-notch (Phf x 1.25) (Watts) =	964	686	1063	1110	(Allowance made for 12-pulse motor)
Total for machine surge circuits (Watts) =	2050	1442	2260	2361	[2 x (Plf + 1.05 x Phf)]
Snubber loss supply side					
Plf (Watts) =	38	39	32	33	[120 x fs² x (Cs)²/(n)² x Ell² x Rs x n x (1 + 0.5 x Sin² Øs)]
Phf (Watts) =	966	1310	265	293	[10.5 x fs x Cs/n x Ell² x (Sin² Øs + Sin² (Øs + μ))]
(μ = 0° per 995 std)					
Total for supply snubber circuits (Watts) =	2007	2698	592	653	[2 x (Plf + Phf)]
Snubber loss machine side					
Plf (Watts) =	40	23	44	46	[120 x fm² x (Cs)²/(n)² x E² x Rs x n x (1 + 0.5 x Sin² Øm)]
Phf (Watts) =	1079	769	1190	1243	[10.5 x fm x Cs/n x E² x (Sin² Øm + Sin² (Øm + μ))]
(μ = 0° per 995 std)					
Adjustment for x-notch (Phf x 1.25) (Watts) =	1349	961	1488	1554	(Allowance made for 12-pulse motor)
Total for machine snubber circuits (Watts) =	2778	1967	3063	3200	[2 x (Plf + 1.05 x Phf)]
Sharing resistor loss supply side					
Plf (Watts) =	719	697	691	724	[4 x Ell²/(n x Re) x (1 + 0.2 x Cos (2 x Øs))]
Total supply side sharing loss (Watts) =	1437	1394	1381	1447	(2 channels)
Sharing resistor loss machine side					
Plf (Watts) =	656	584	724	756	[4 x E²/(n x Re) x (1 + 0.2 x Cos (2 x Øm))]
Total machine side sharing loss (Watts) =	1313	1168	1448	1512	(2 channels)
Sections 5.3.5.5 & 5.3.5.6	**Auxiliary control power consumption**				
Measured control power losses from test					*(All normal control power including cooling pump and SCR gate power)*
(Space heaters excluded)					
3 phase 480 V power per channel (Watts) =	1205	1205	1205	1205	
1 phase 120 V power per channel (Watts) =	330	330	330	330	
Total control power consumption (Watts) =	3070	3070	3070	3070	(2 channels)
Miscellaneous	**Ground fault detection circuit losses (not accounted for by IEEE 995)**				
Loss in 3 phase, 13,500 Ohm circuit (Watts) =	2226	1981	2454	2564	[2 x (E/1.7321)²/13,500 x 3]
Total of all losses (Watts) =	49161	30883	45496	45214	[Sum of underlined values above]
Guaranteed loss maximum (Watts) =	55316	N/A	N/A	N/A	(Based on 1% loss or 99% efficiency)
Operating output power level (Watts) =	5531590	2832174	5531590	5531590	[Hp x 746]
Overall Operating Efficiency (%) =	**99.12**	**98.92**	**99.18**	**99.19**	[Output/(Output + losses) x 100]



IP7015138



IP7015139



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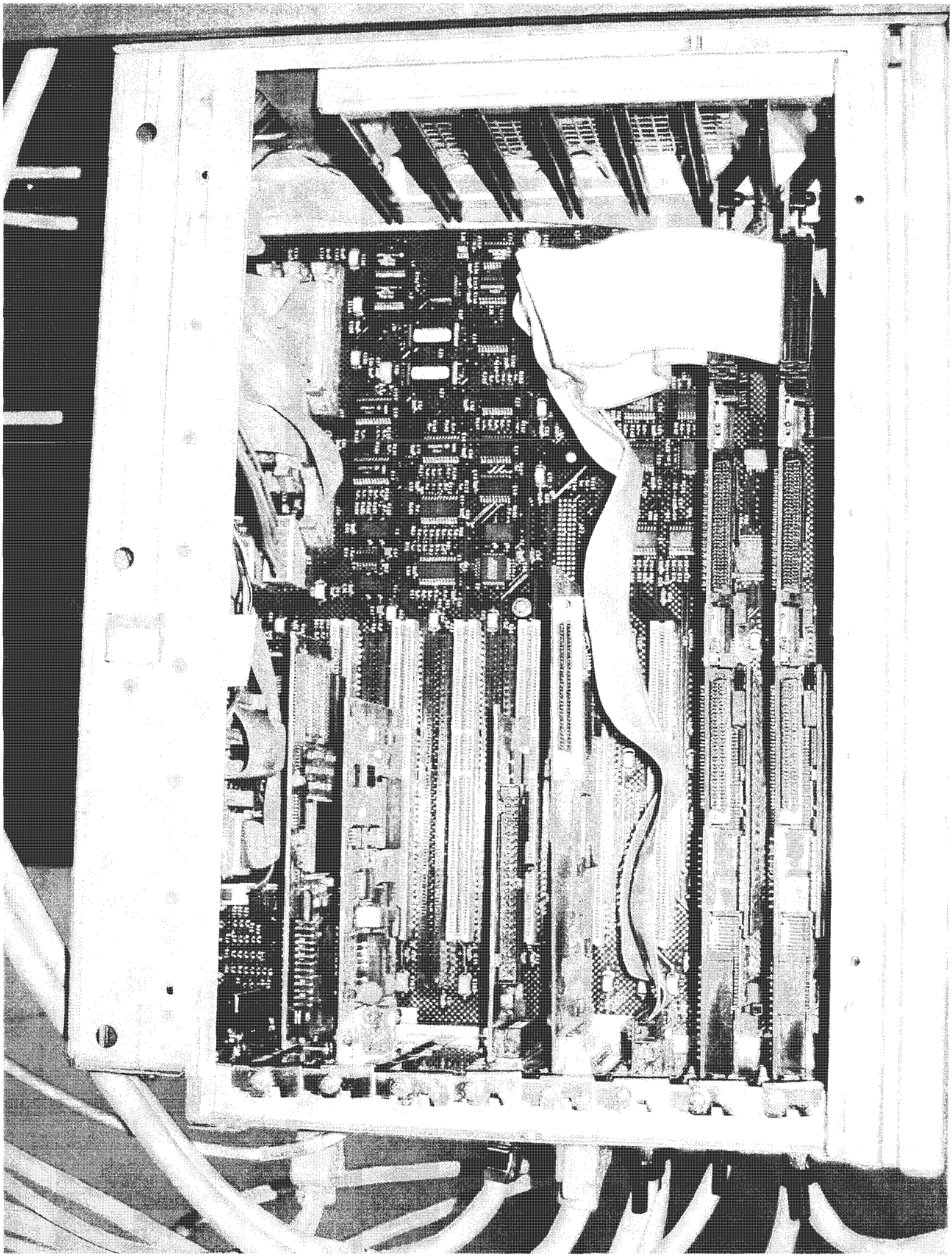

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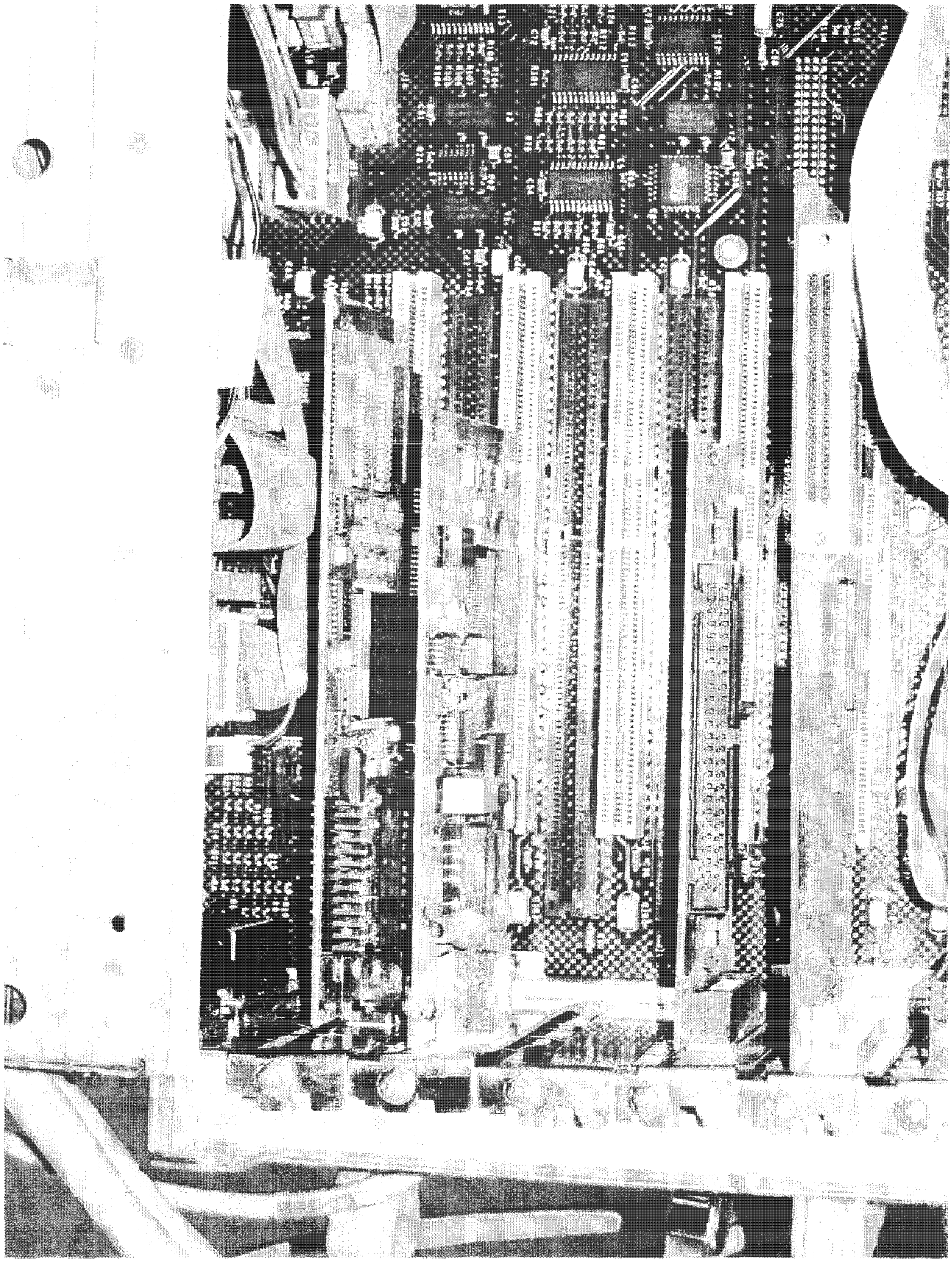

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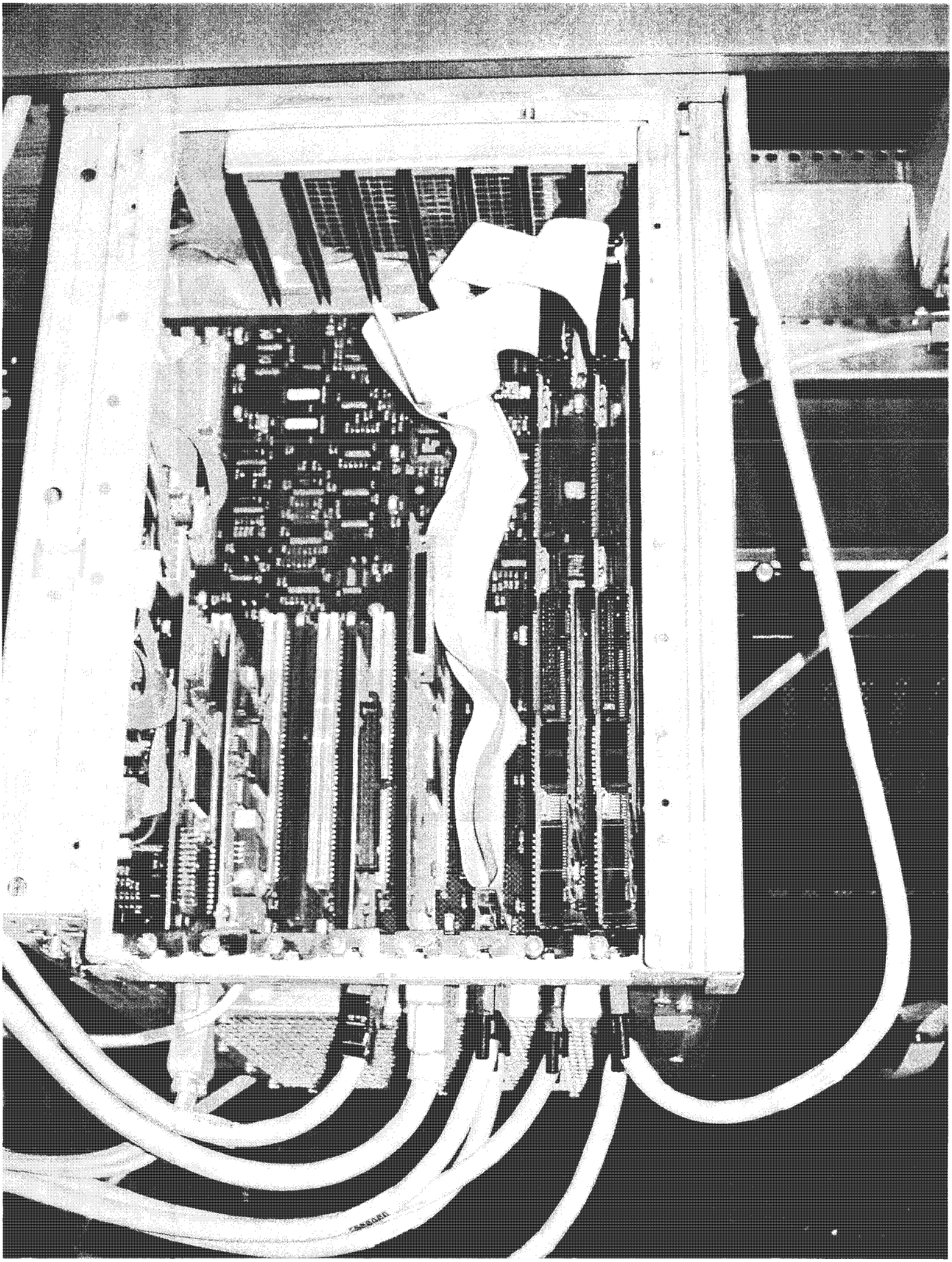

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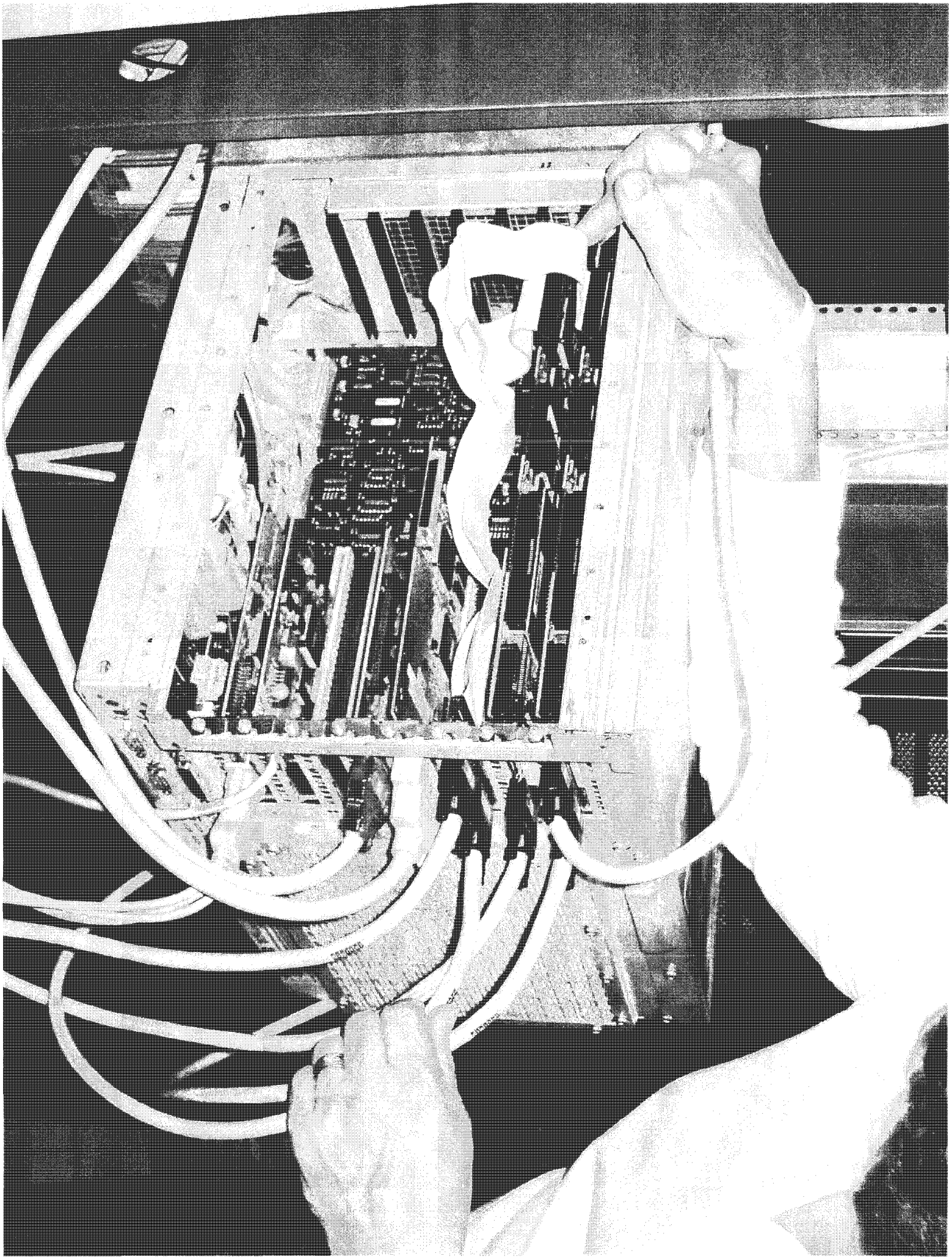

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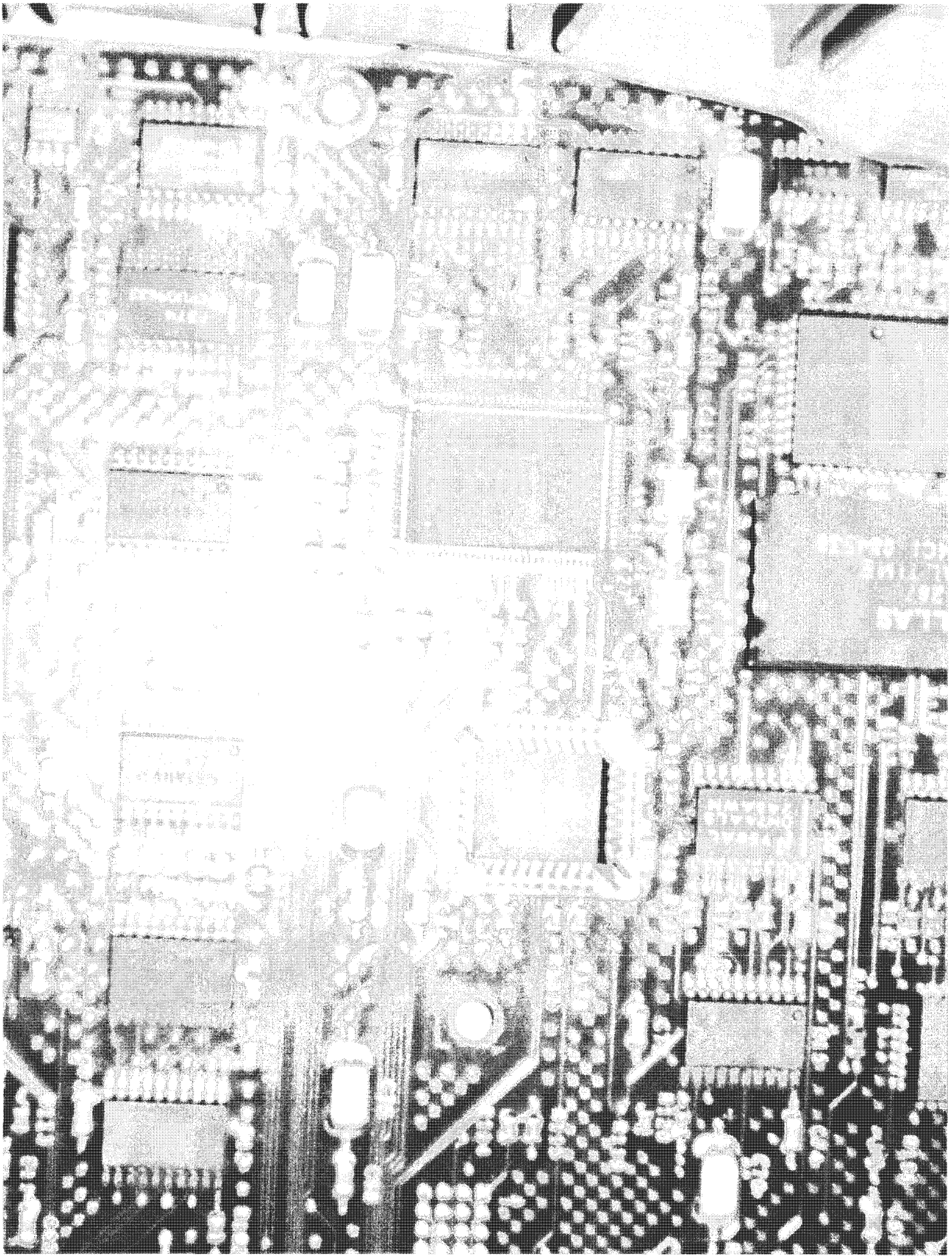

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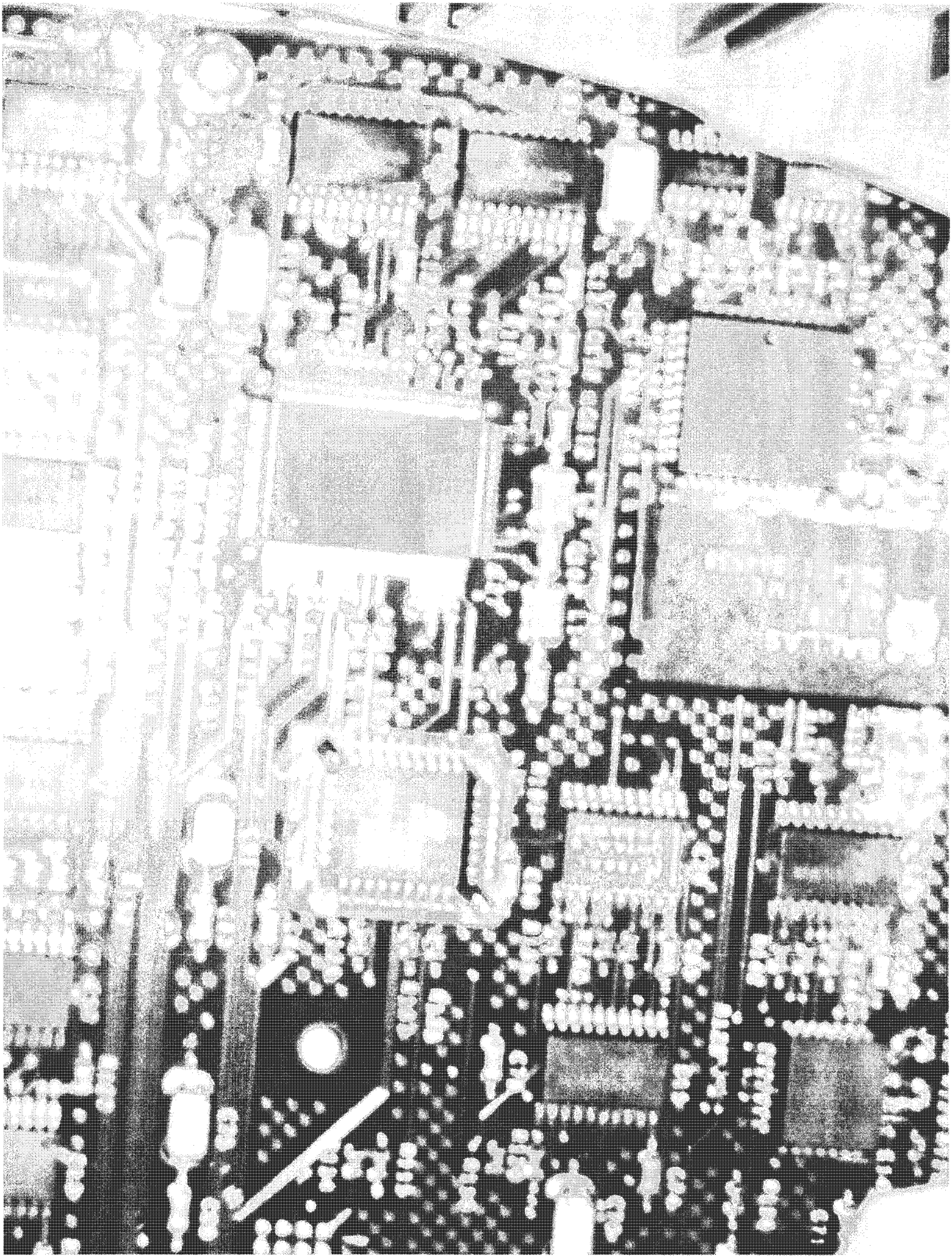

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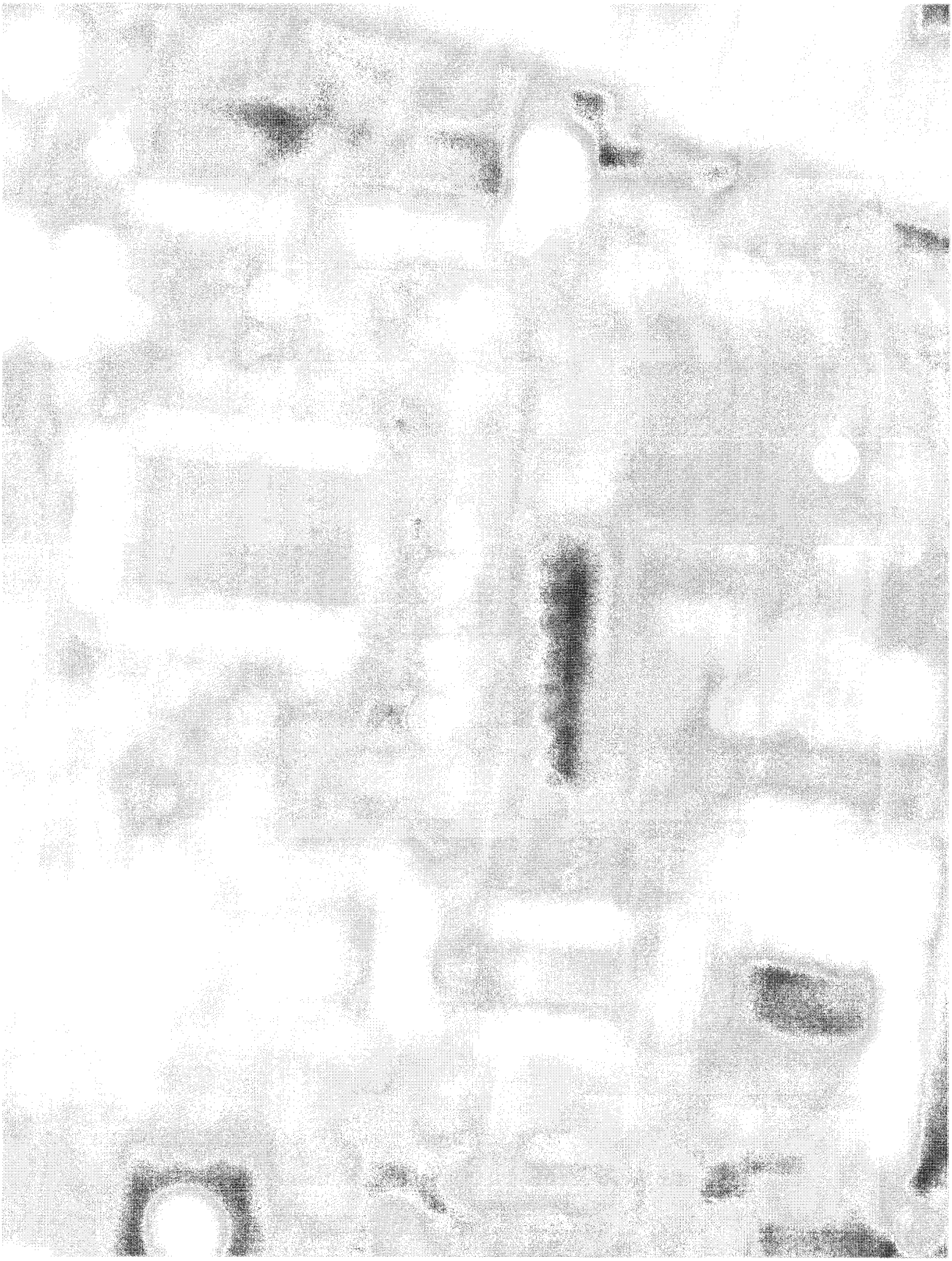

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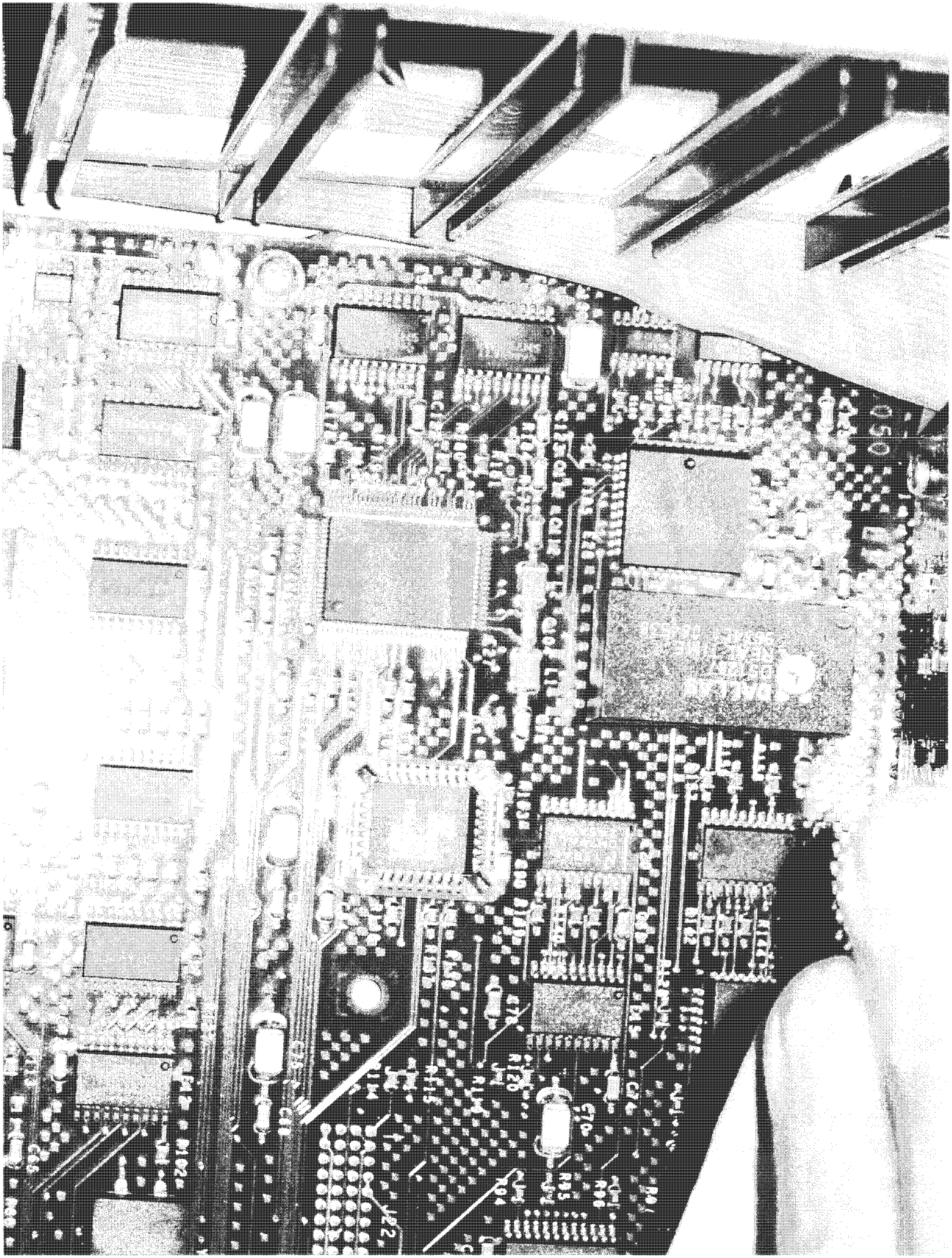

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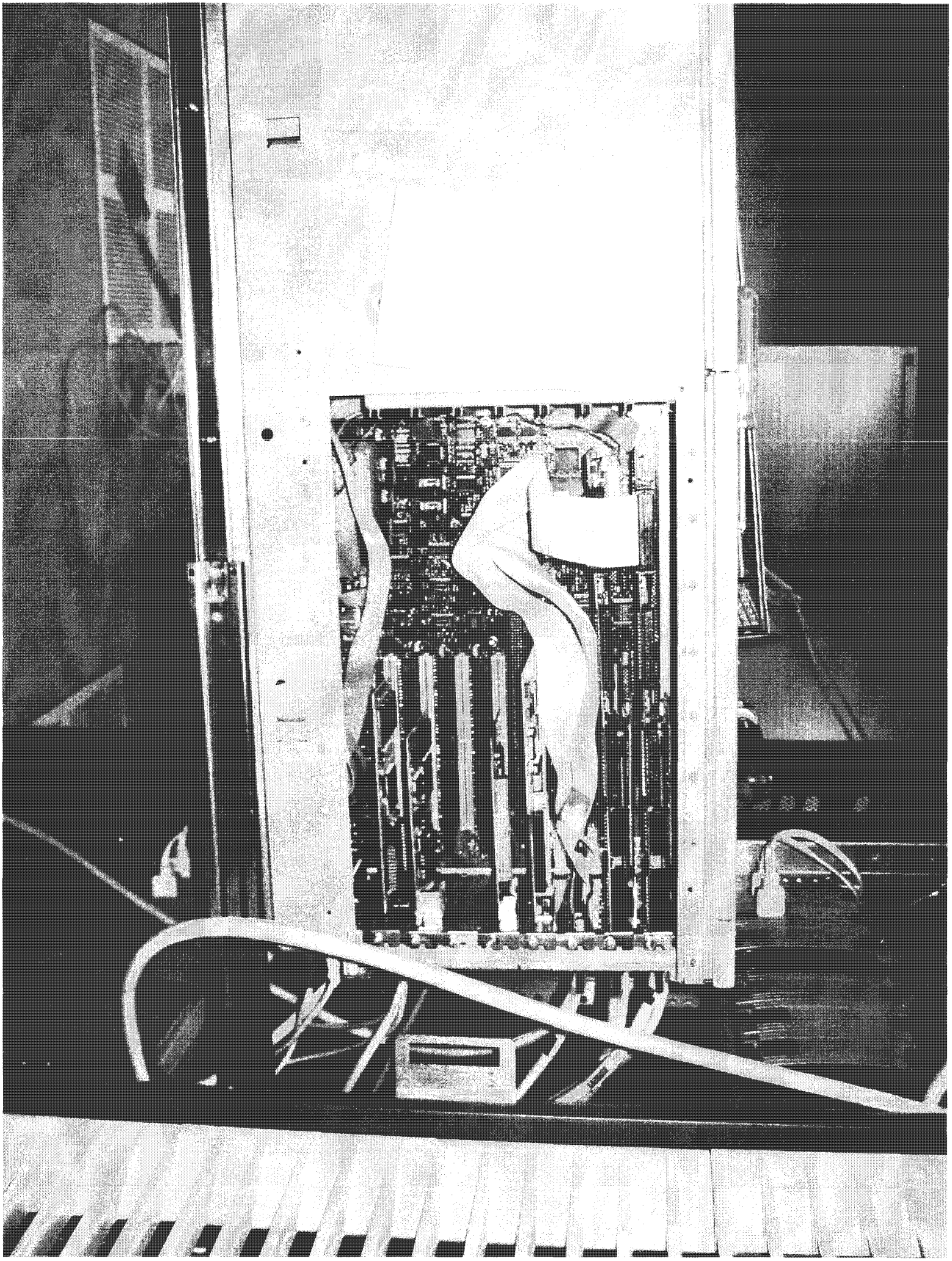

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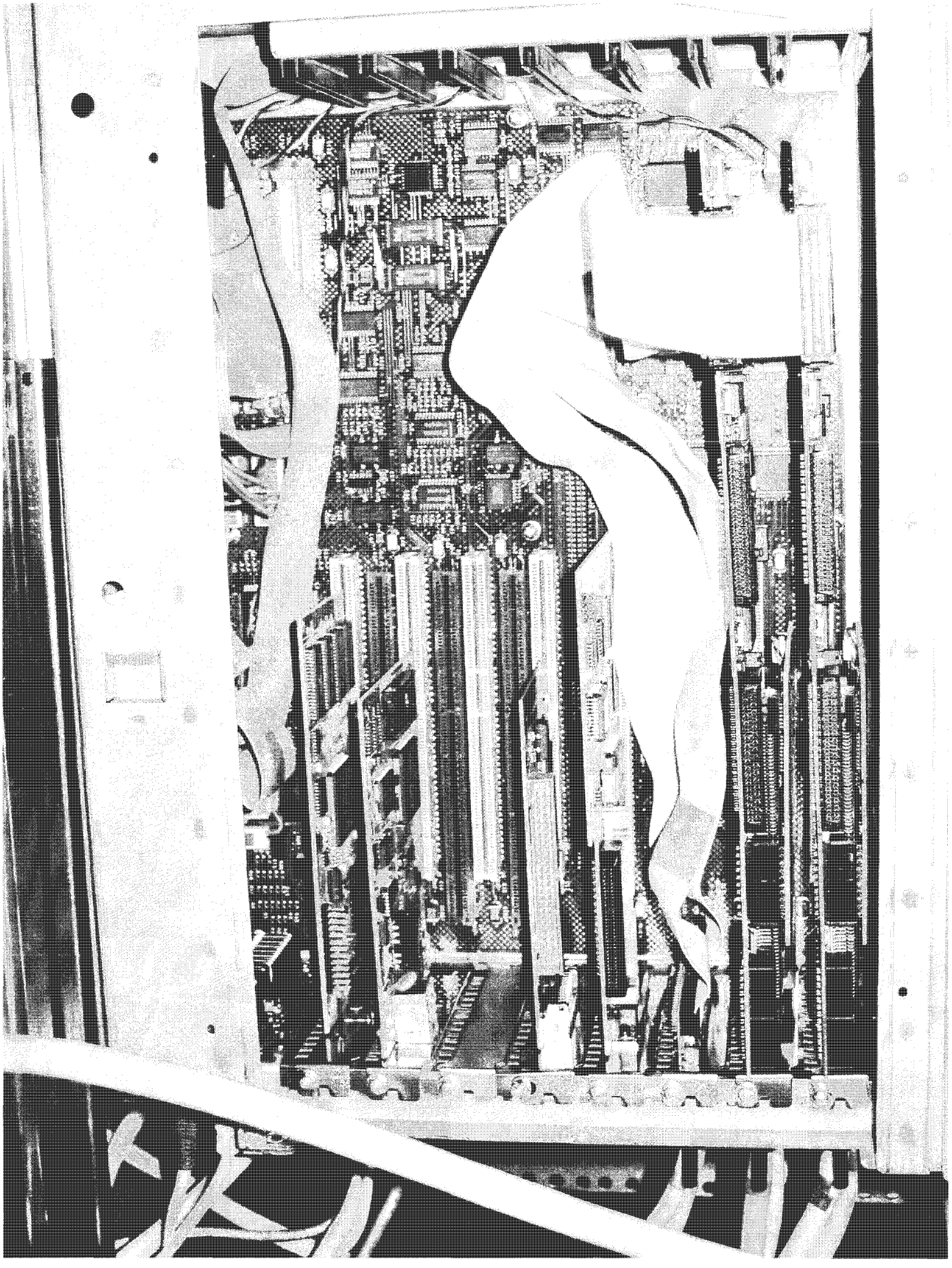

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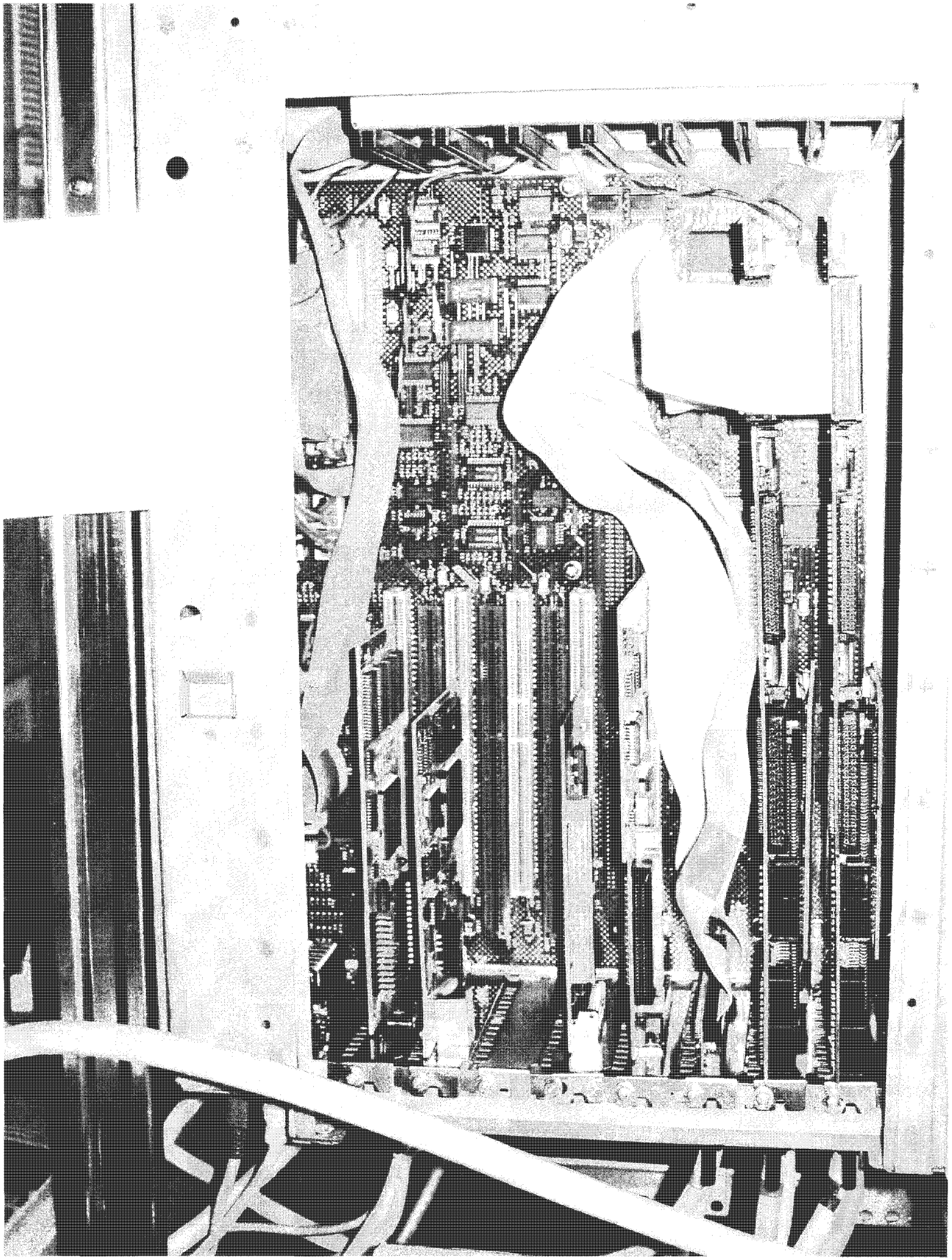

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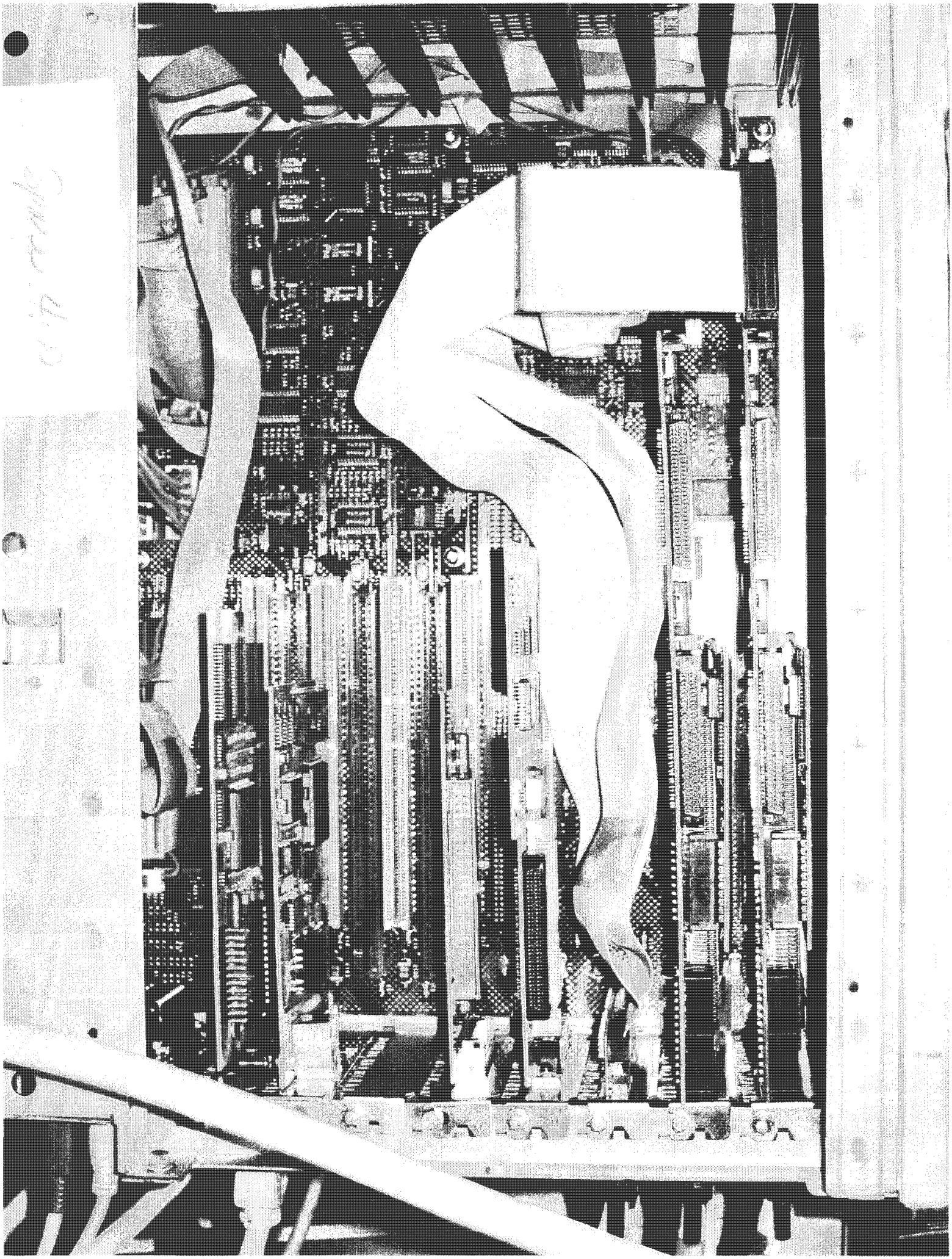

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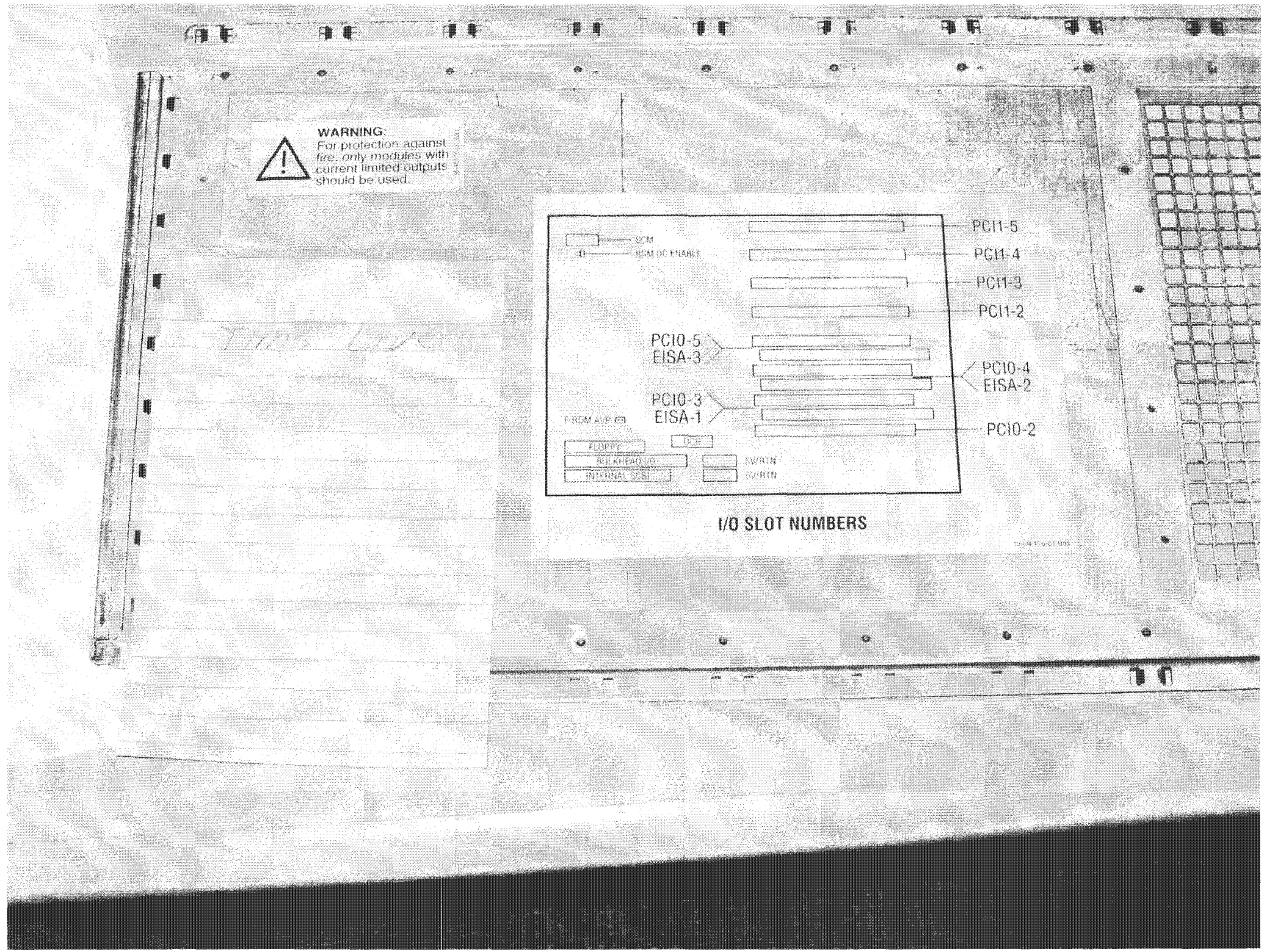
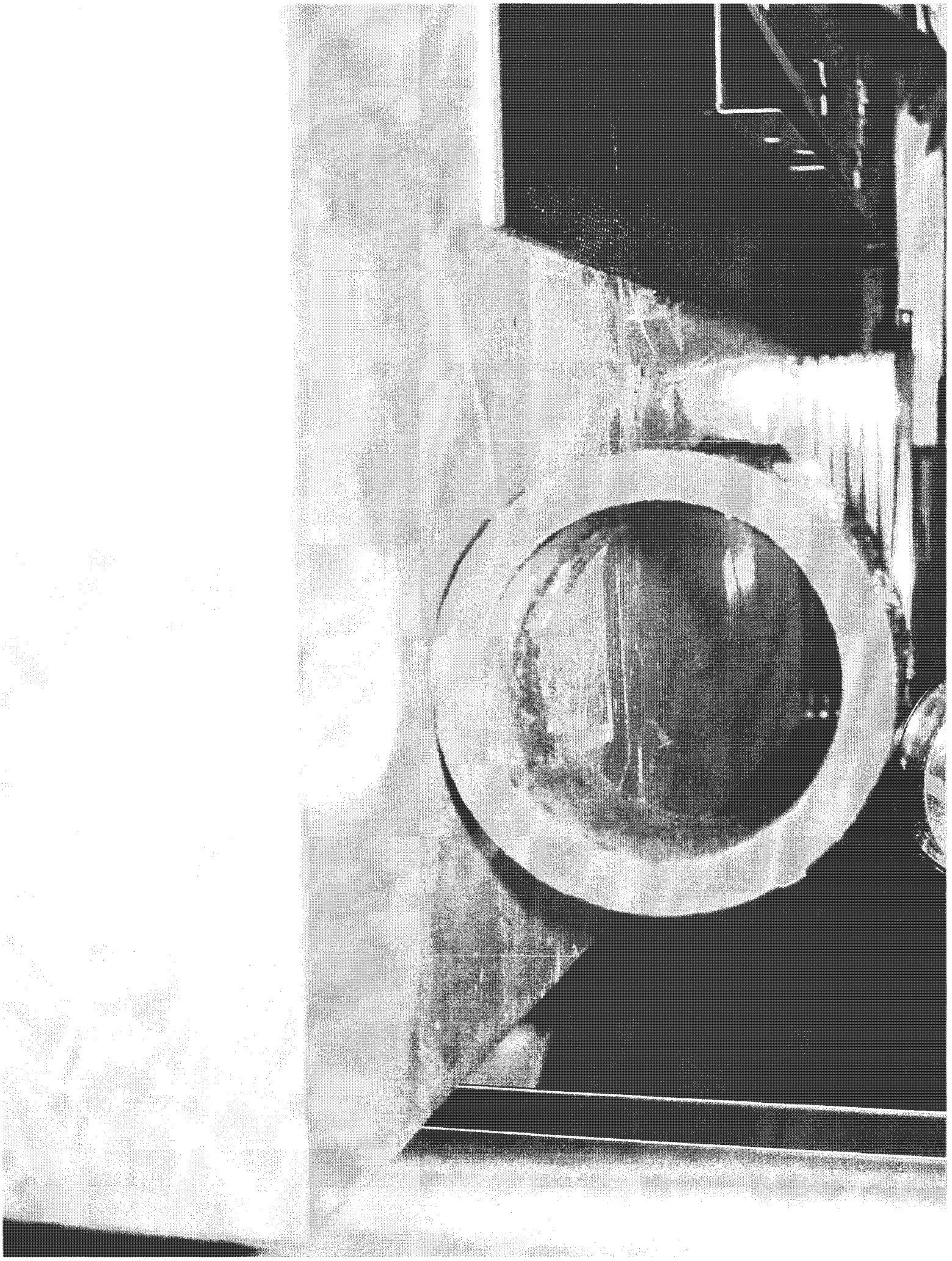

WARNING:
For protection against fire, only modules with current limited outputs should be used.
PCI1-5
PCI1-4
PCI1-3
PCI1-2
PCI0-5
EISA-3
PCI0-4
EISA-2
PCI0-3
EISA-1
PCI0-2
FLOPPY
BULKHEAD I/O
INTERNAL SCSI
I/O SLOT NUMBERS

IP7015153



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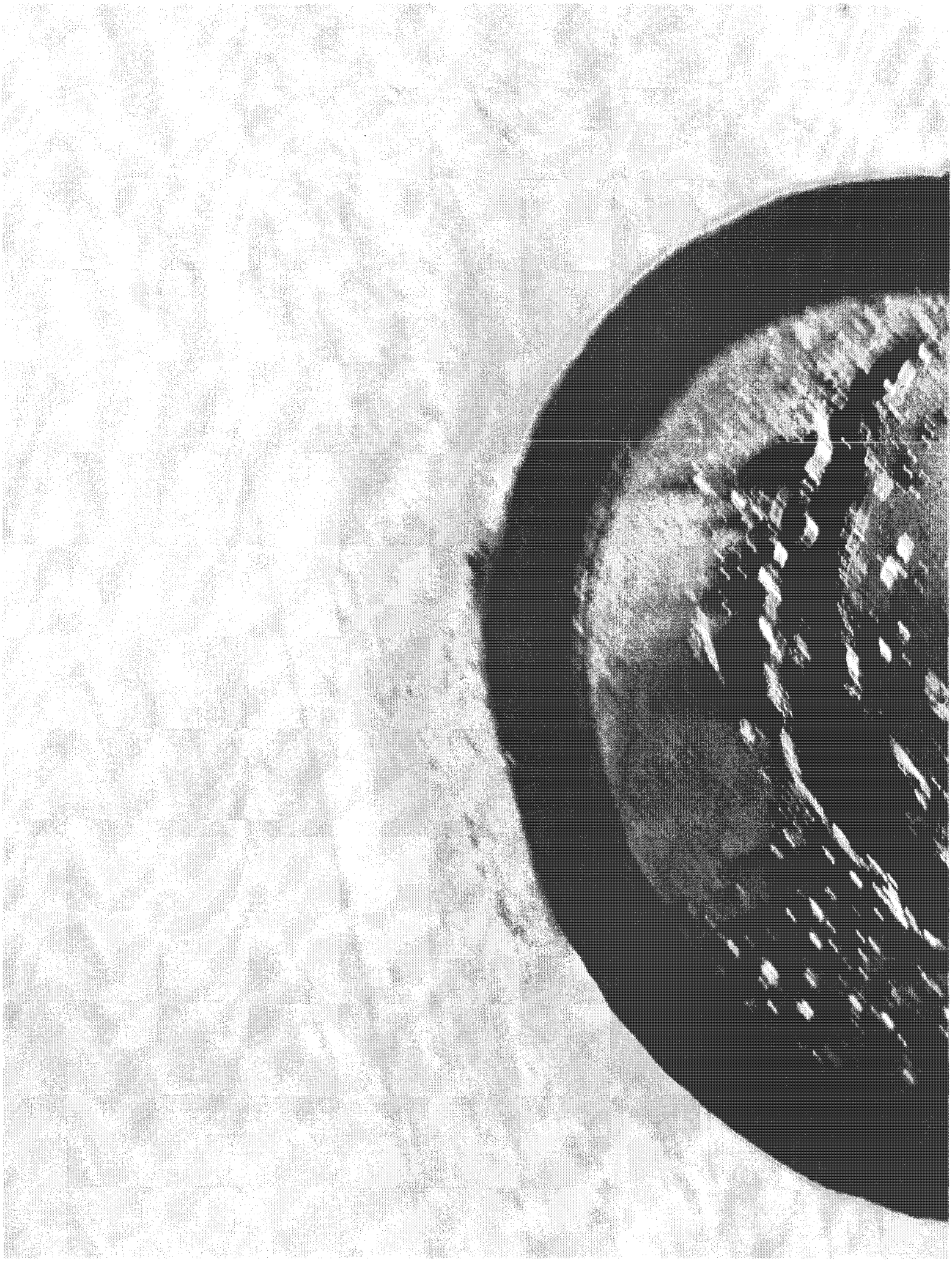

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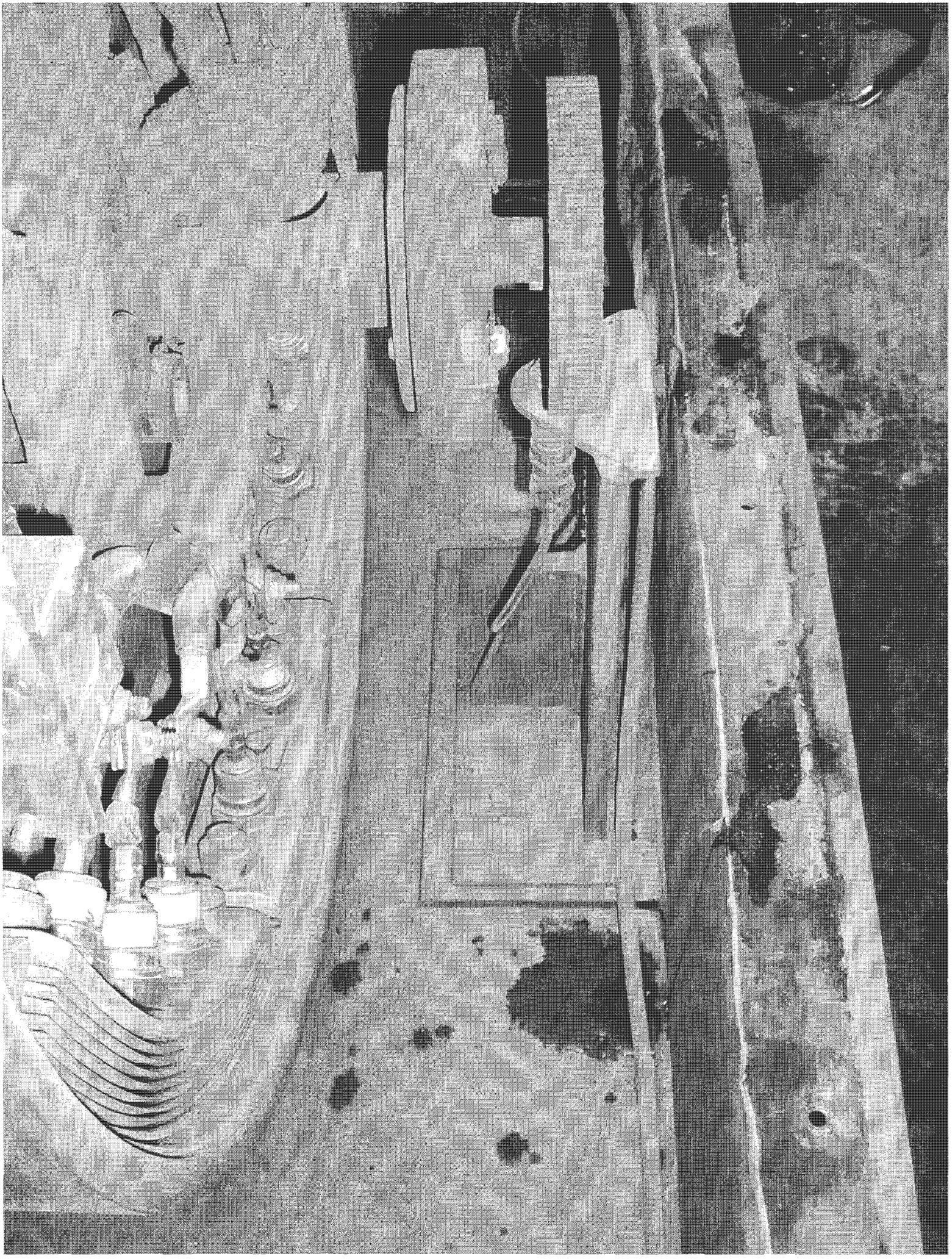

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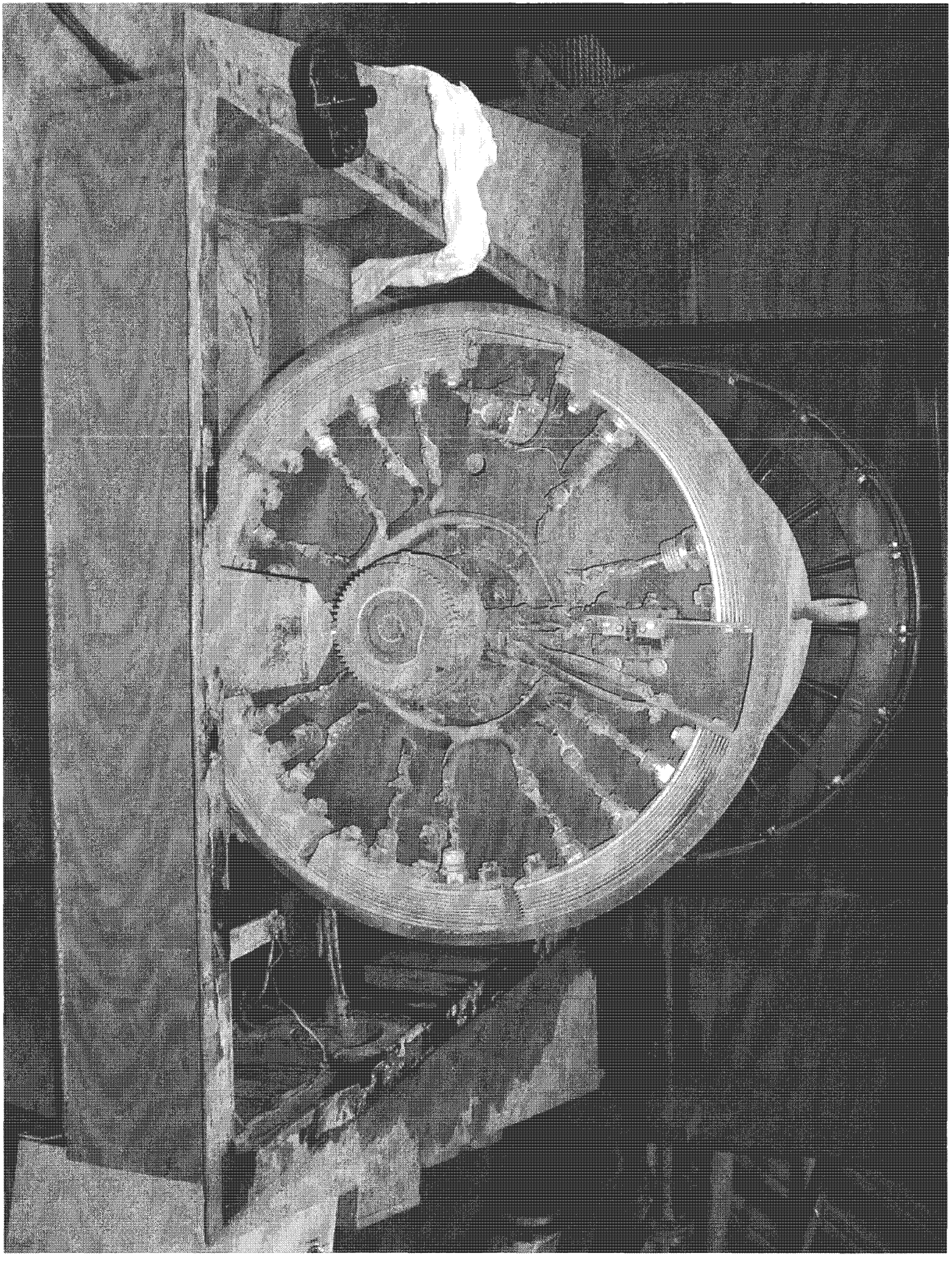

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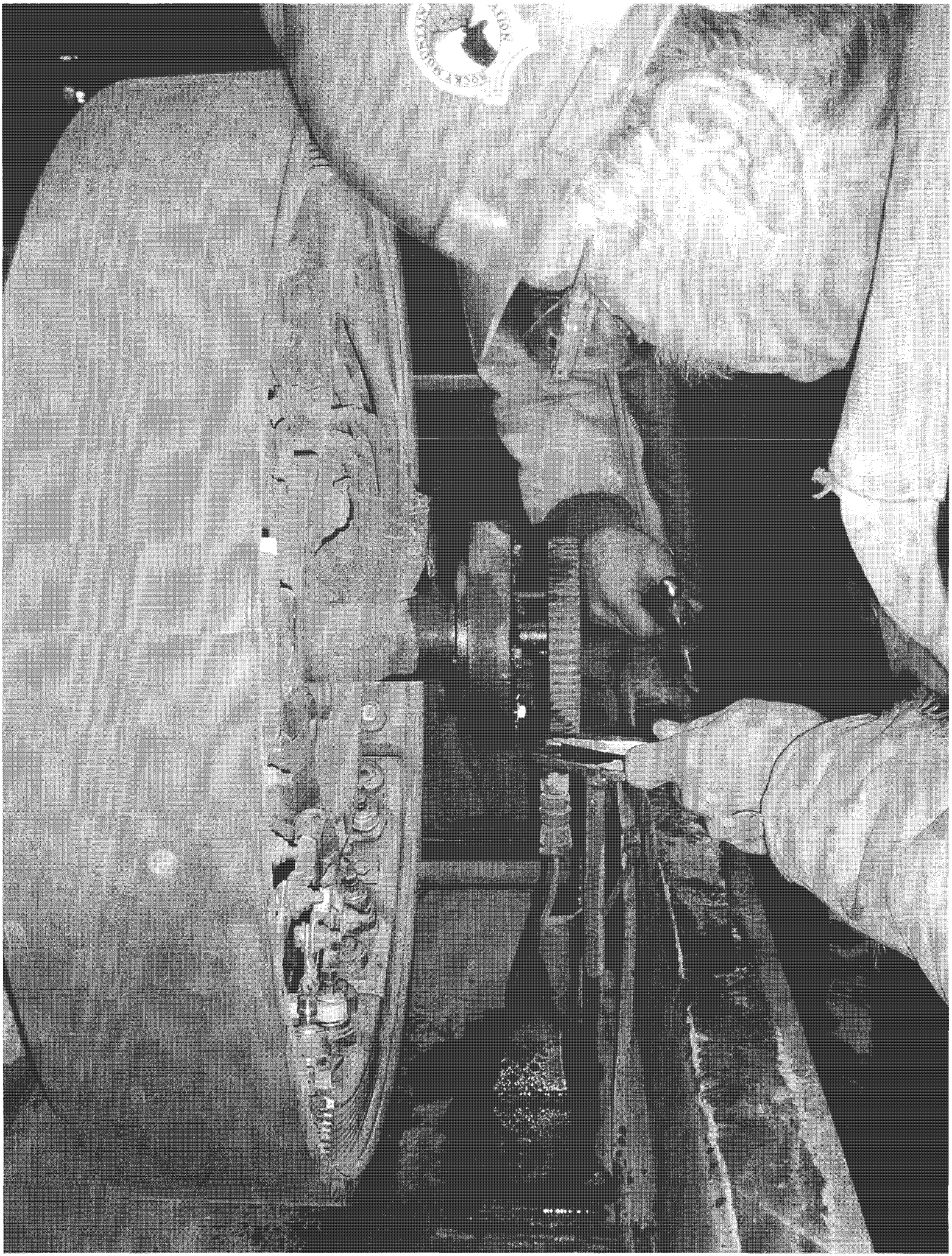

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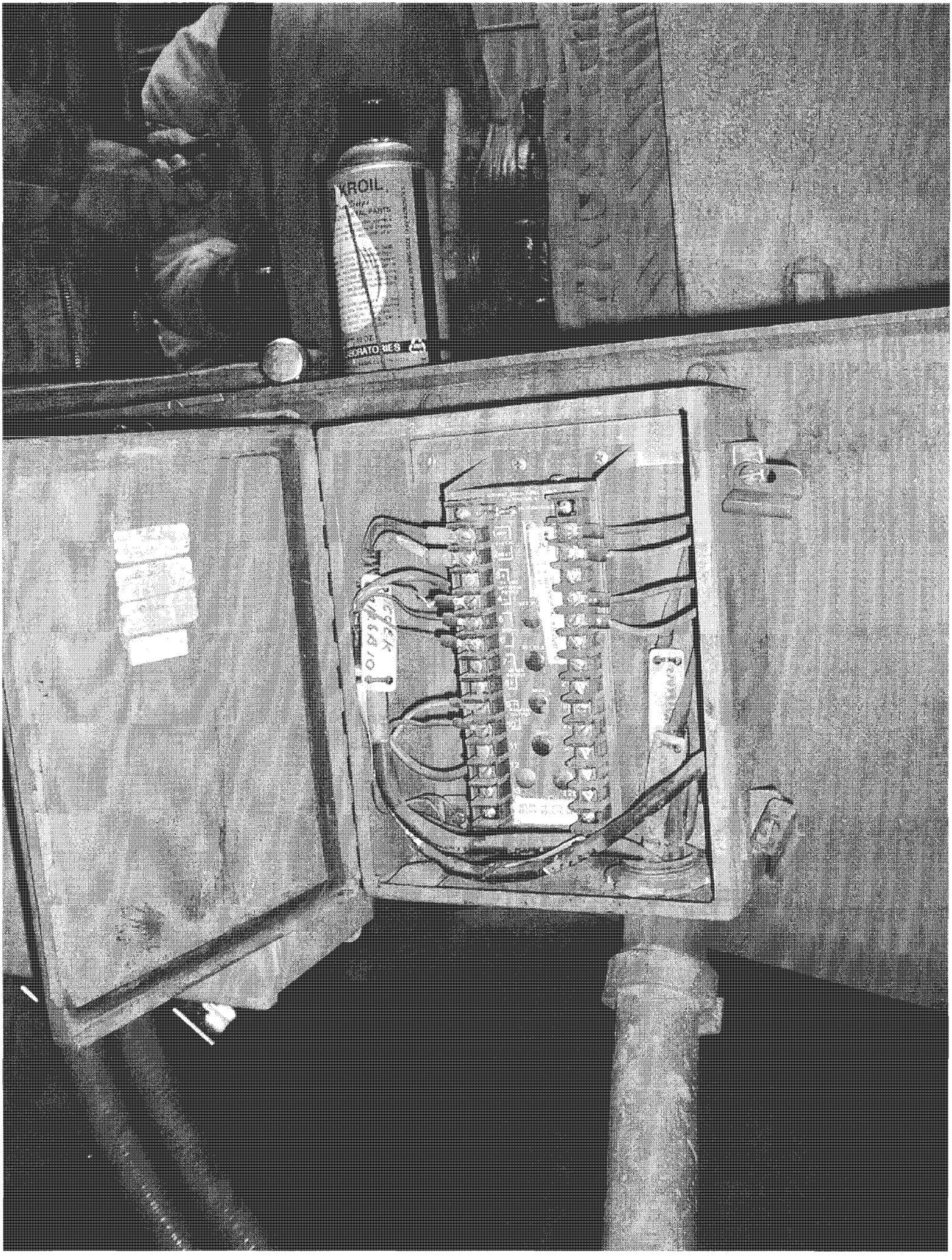
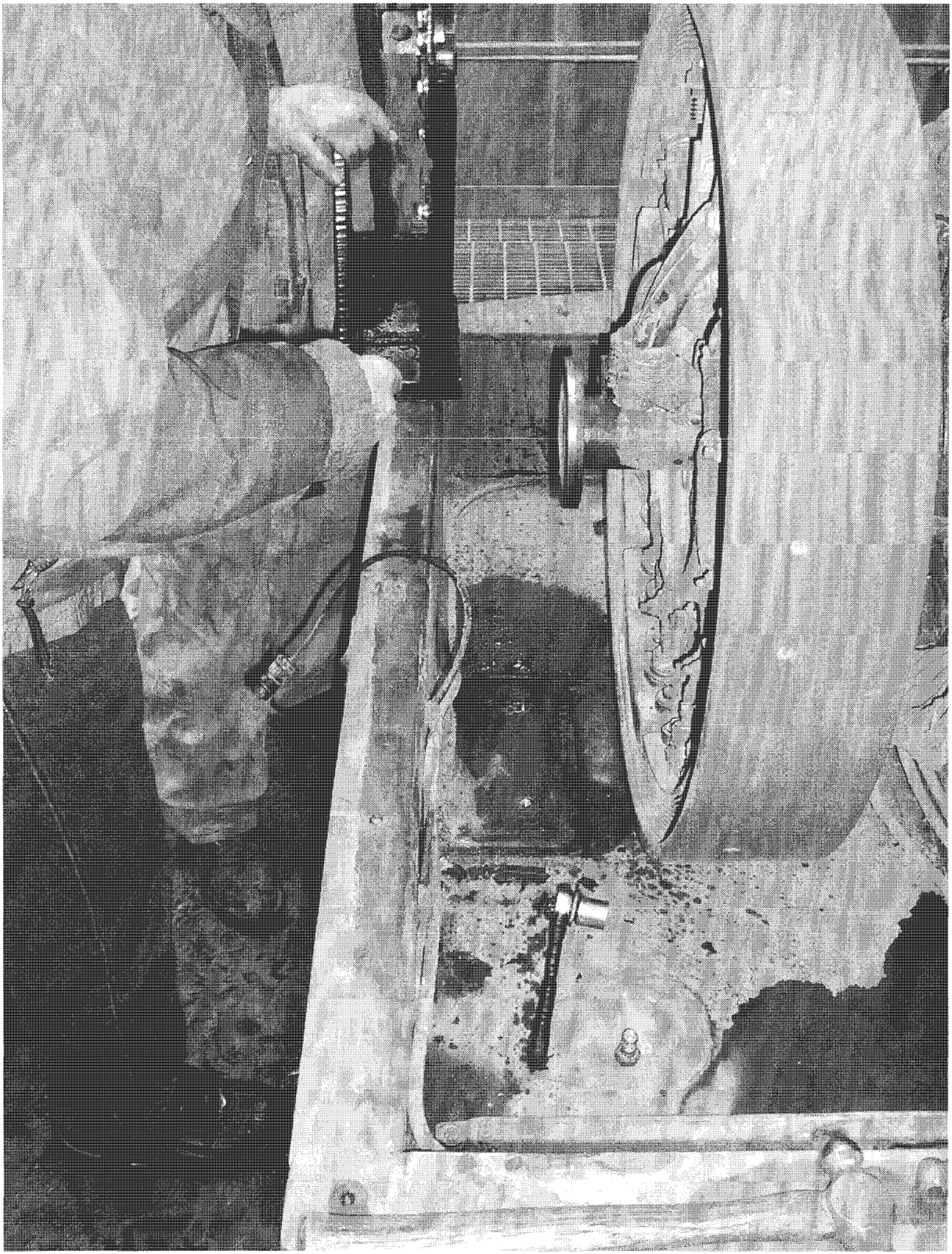


IP7015159

IP7015160

IP7015161



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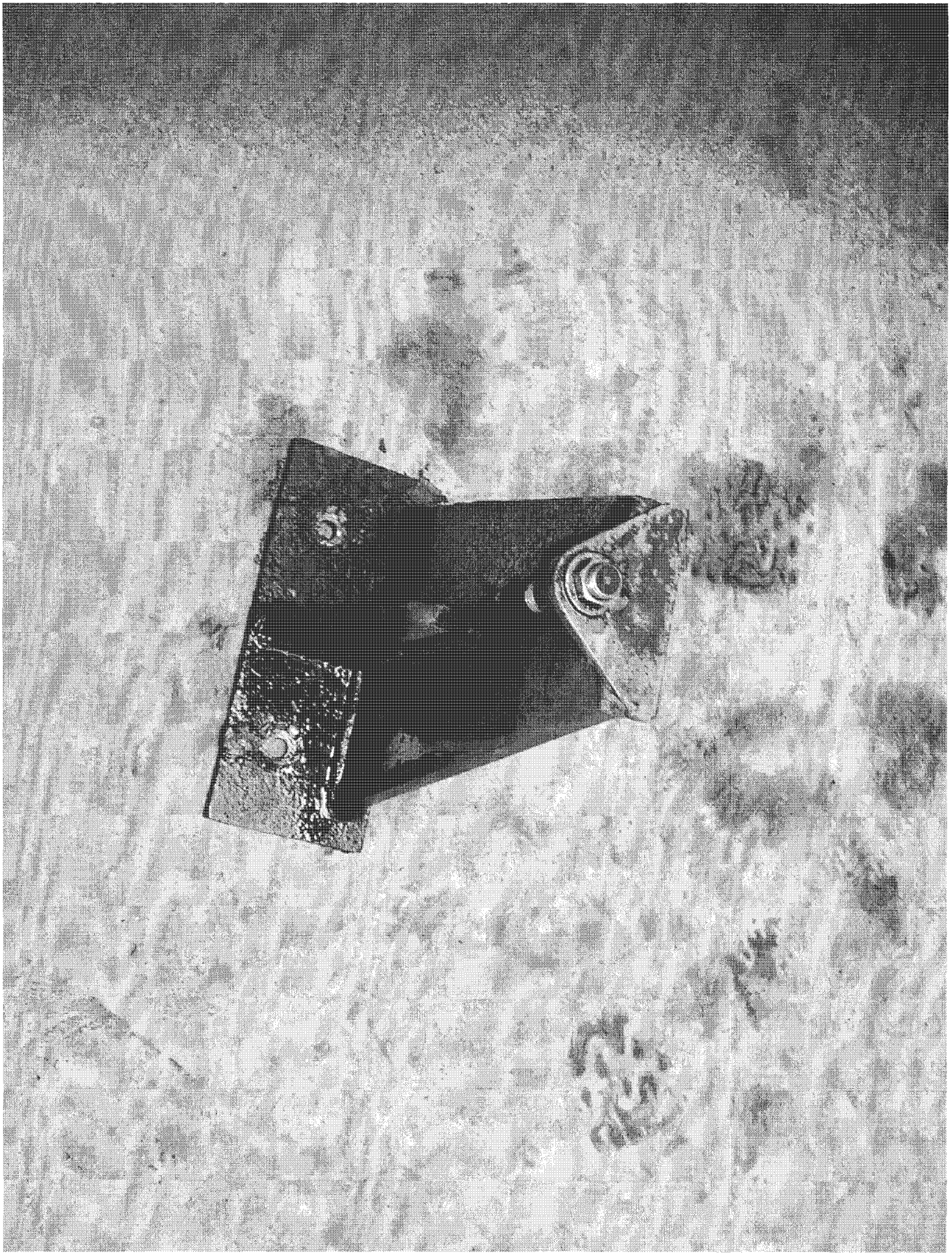

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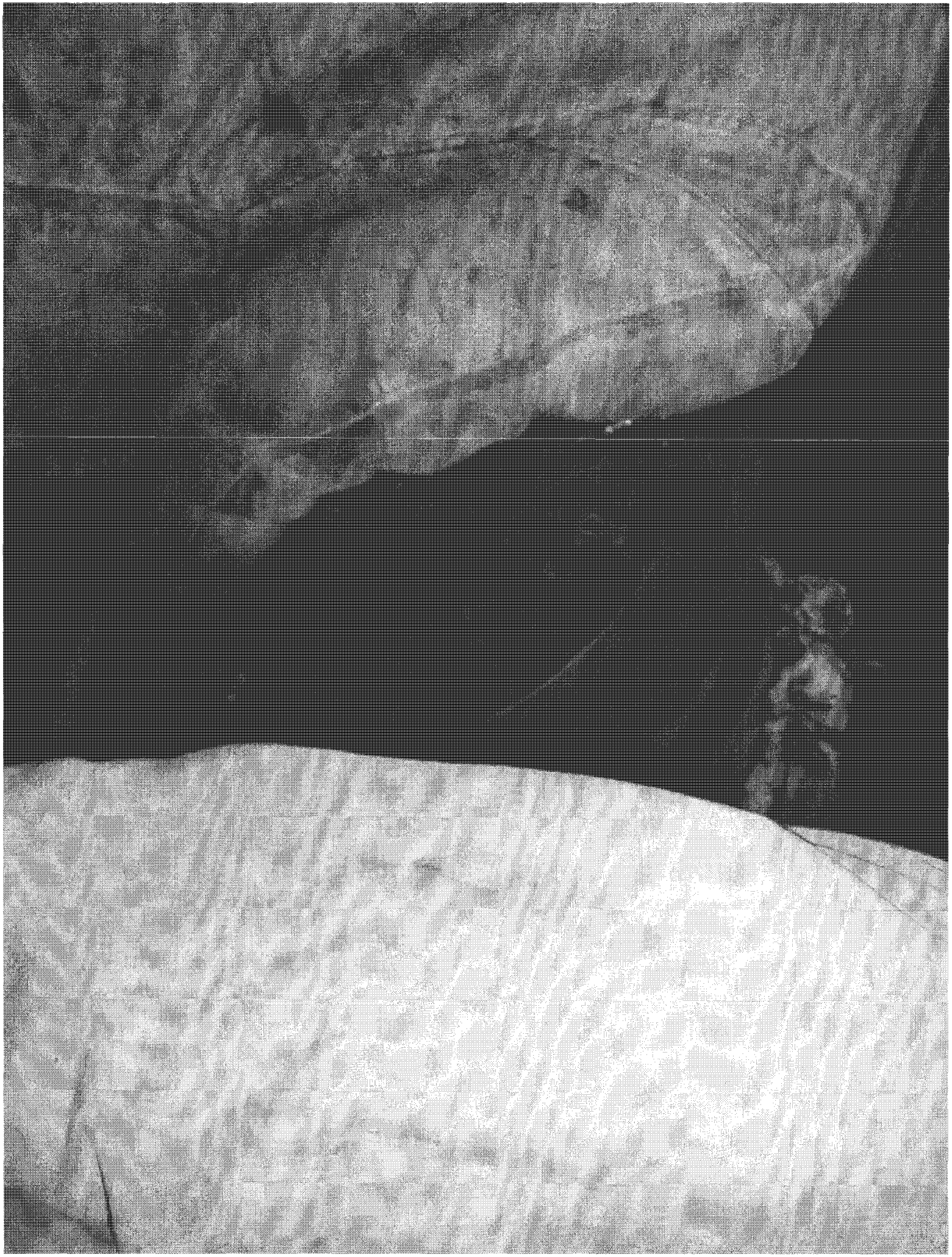

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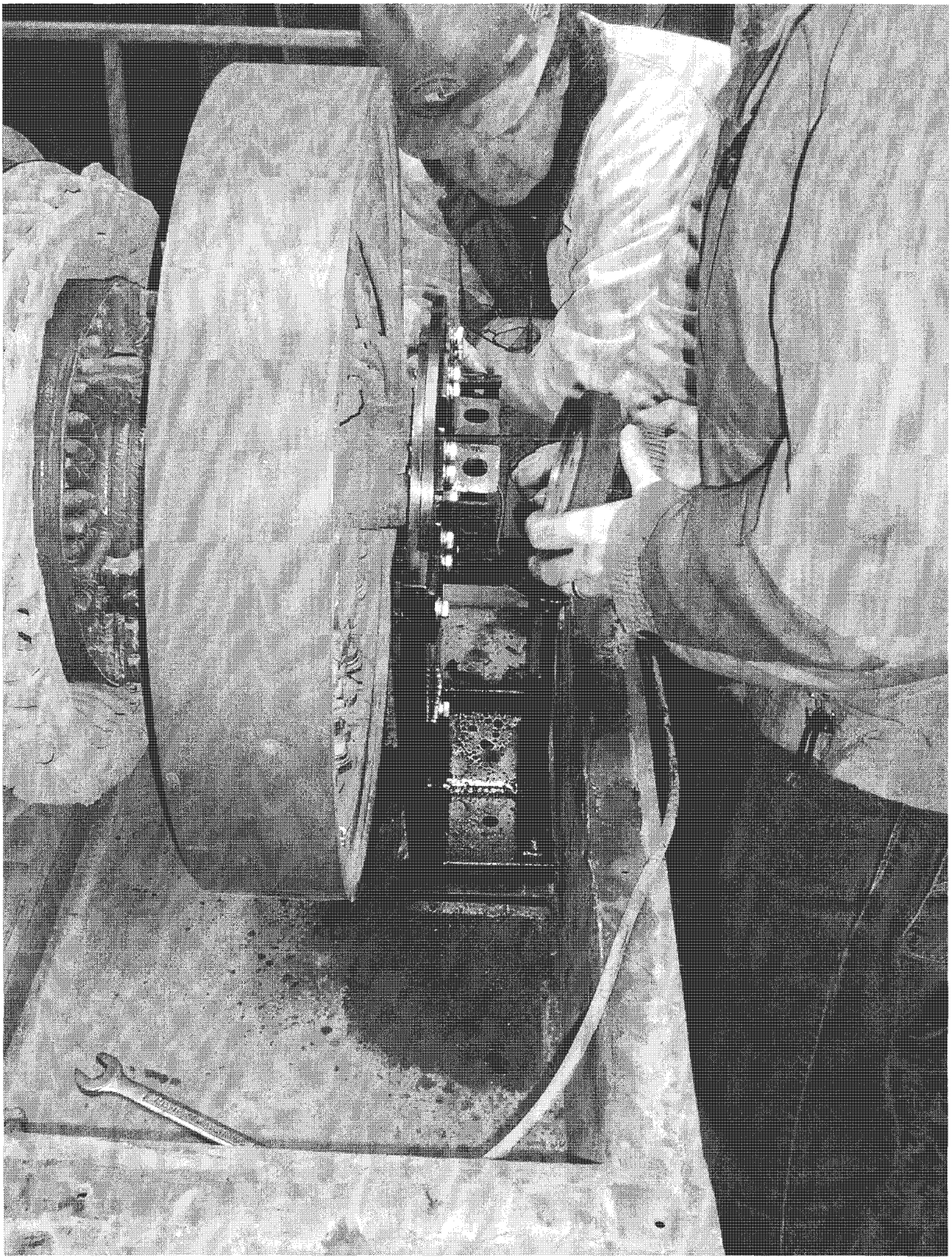

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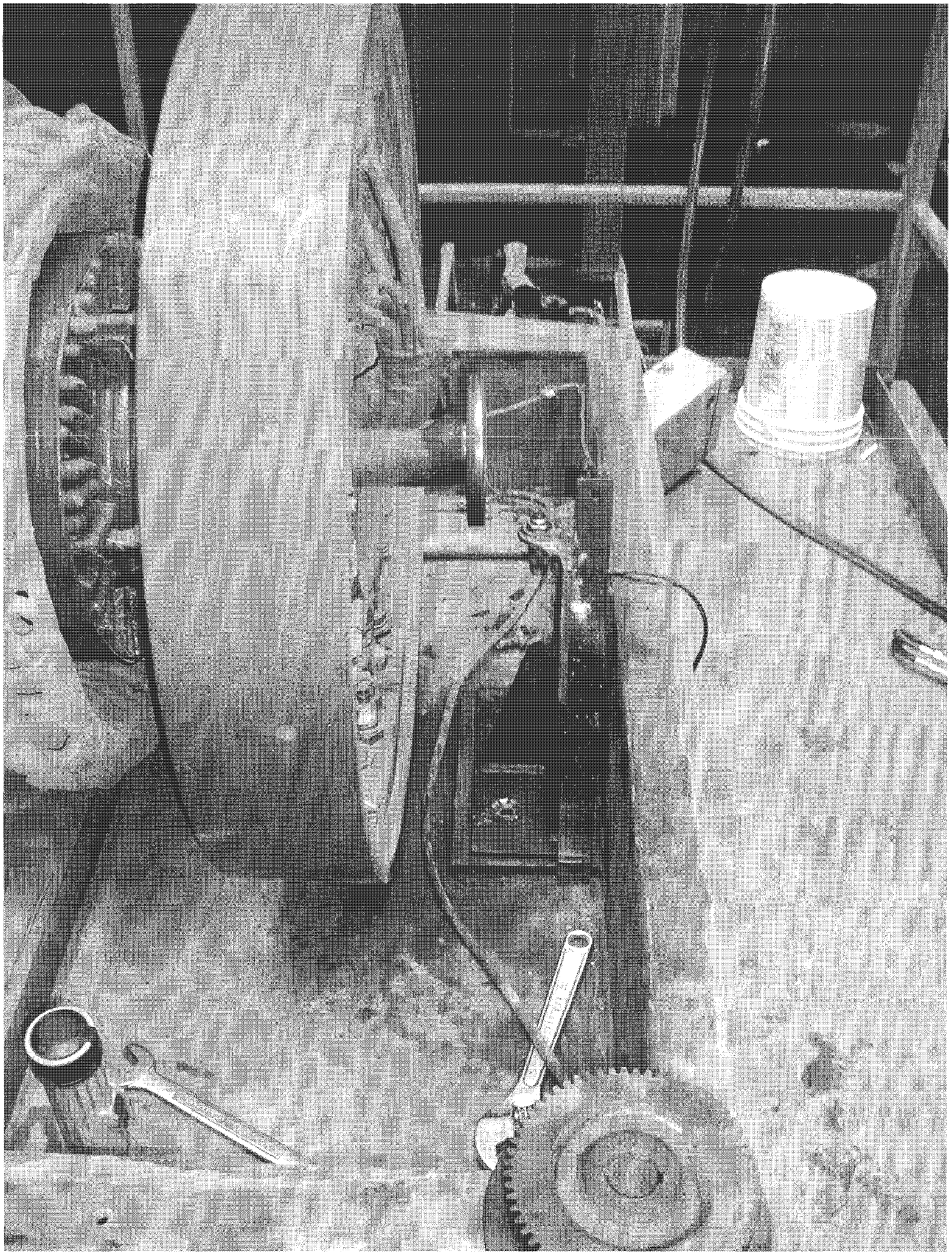

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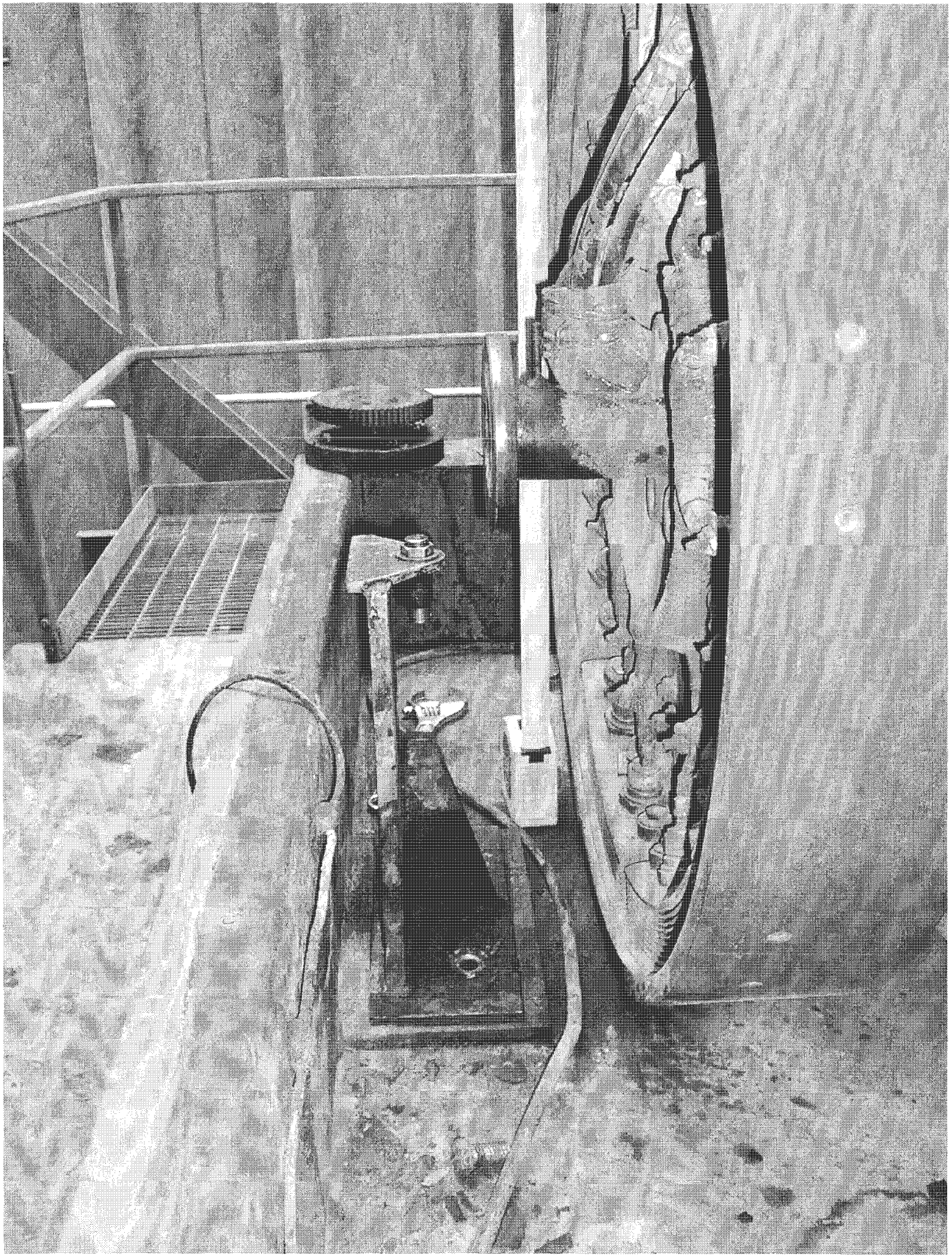

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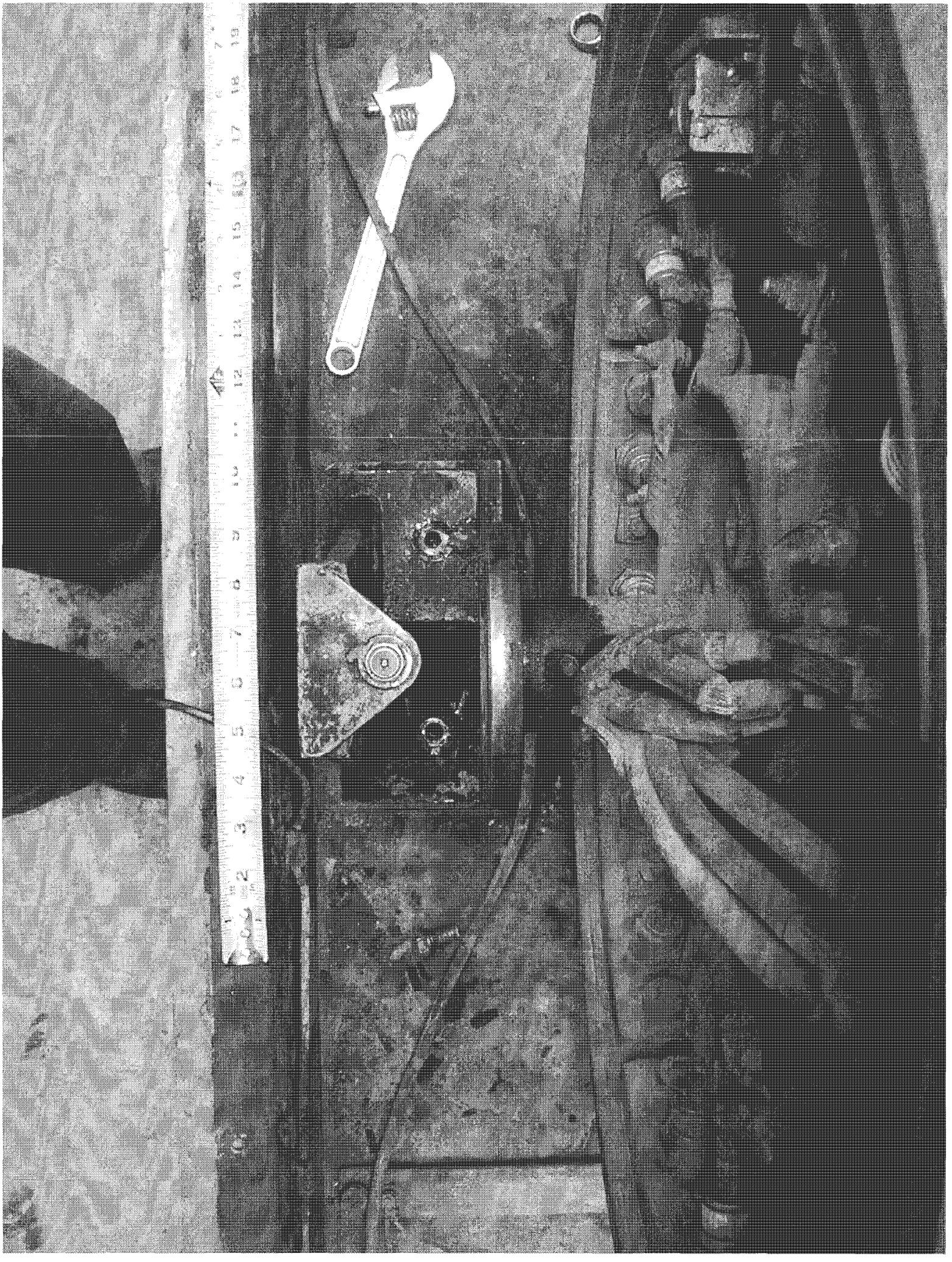

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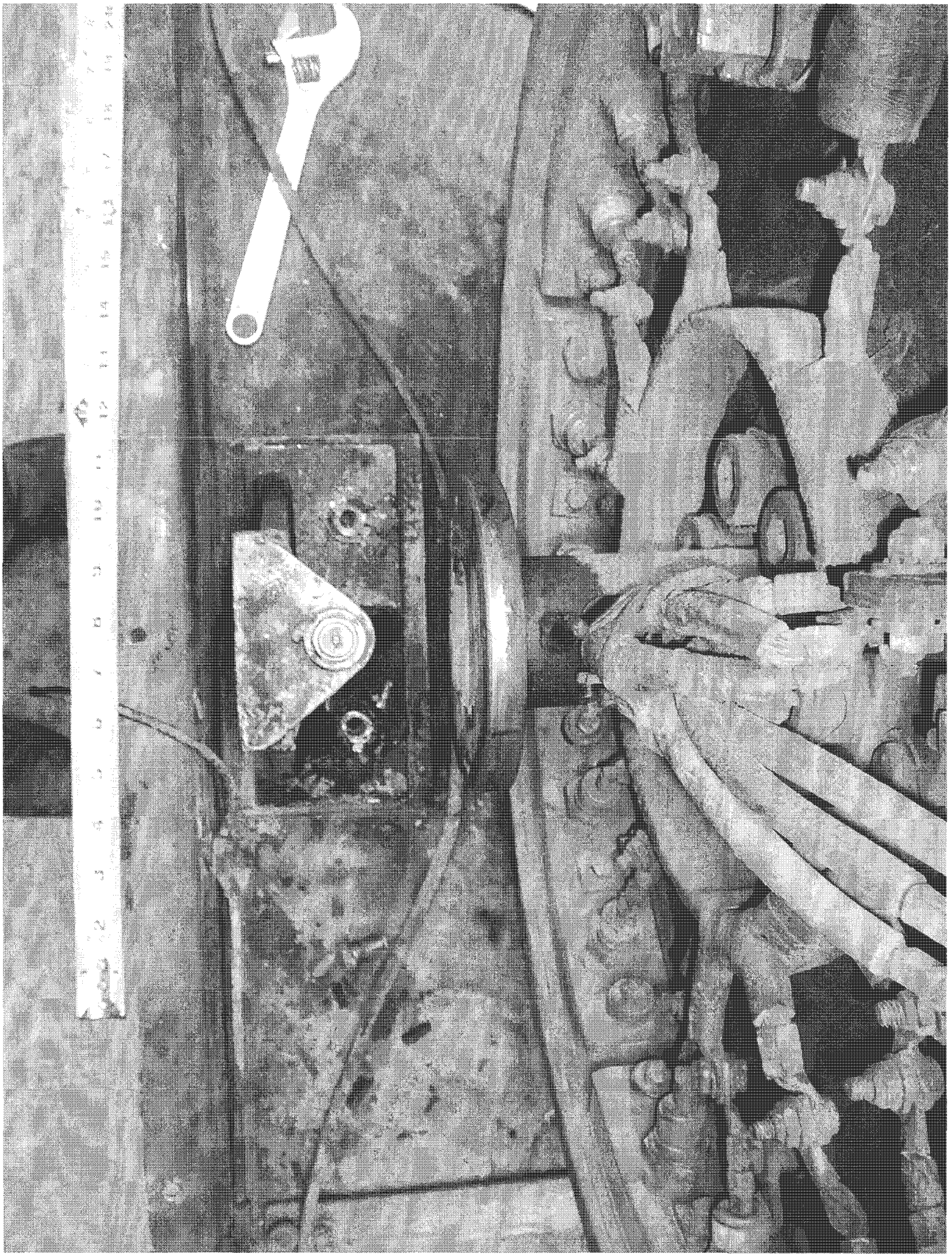

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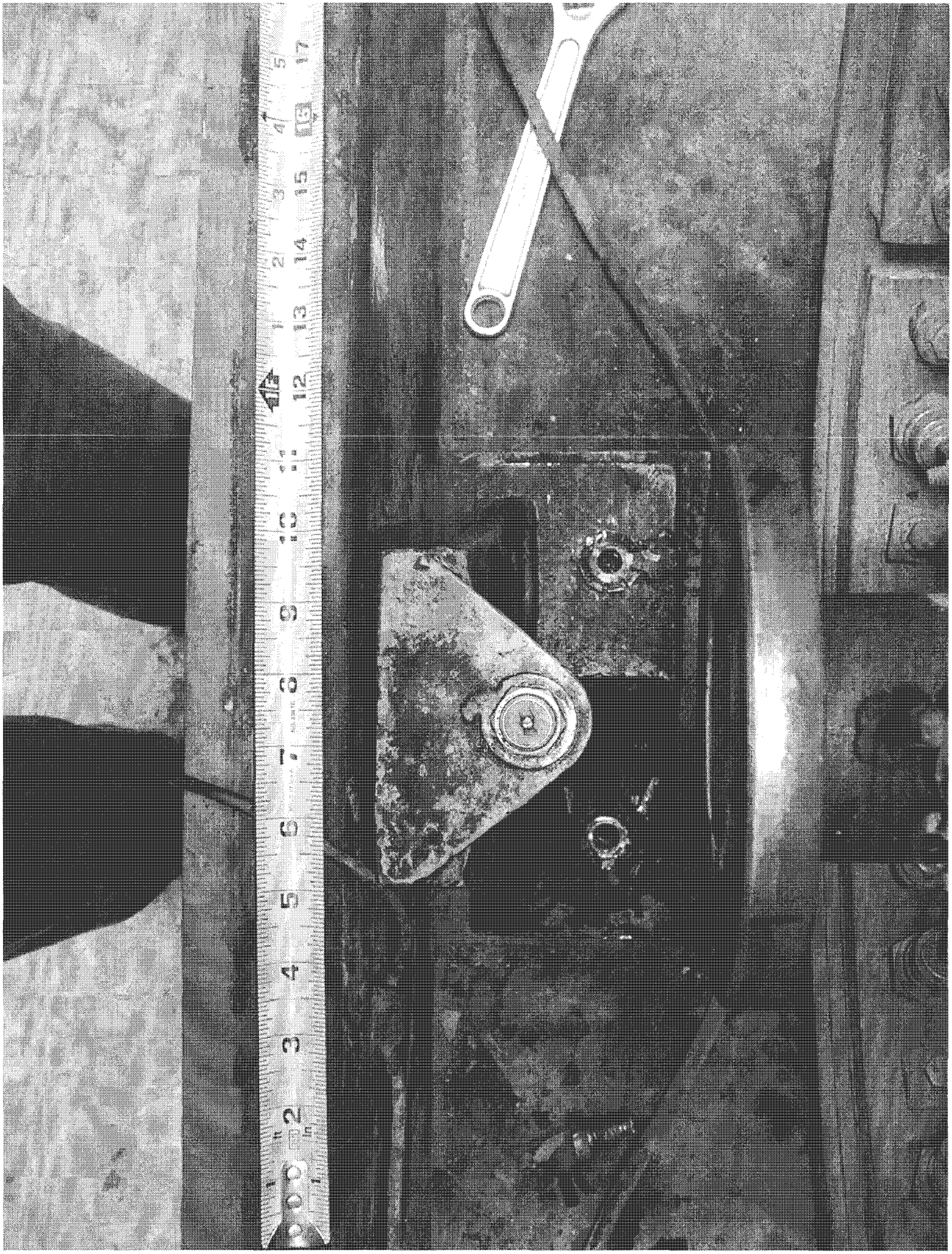

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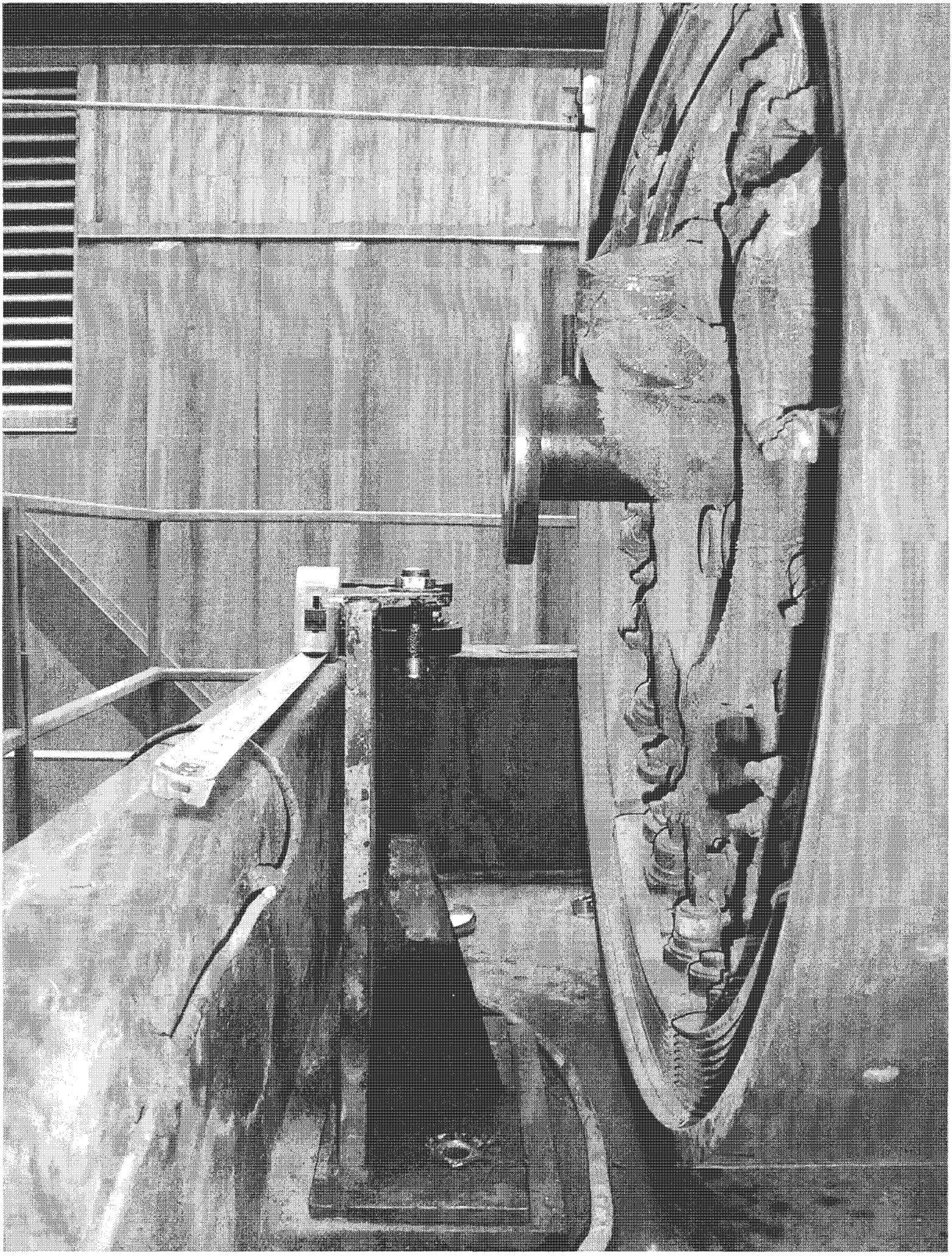

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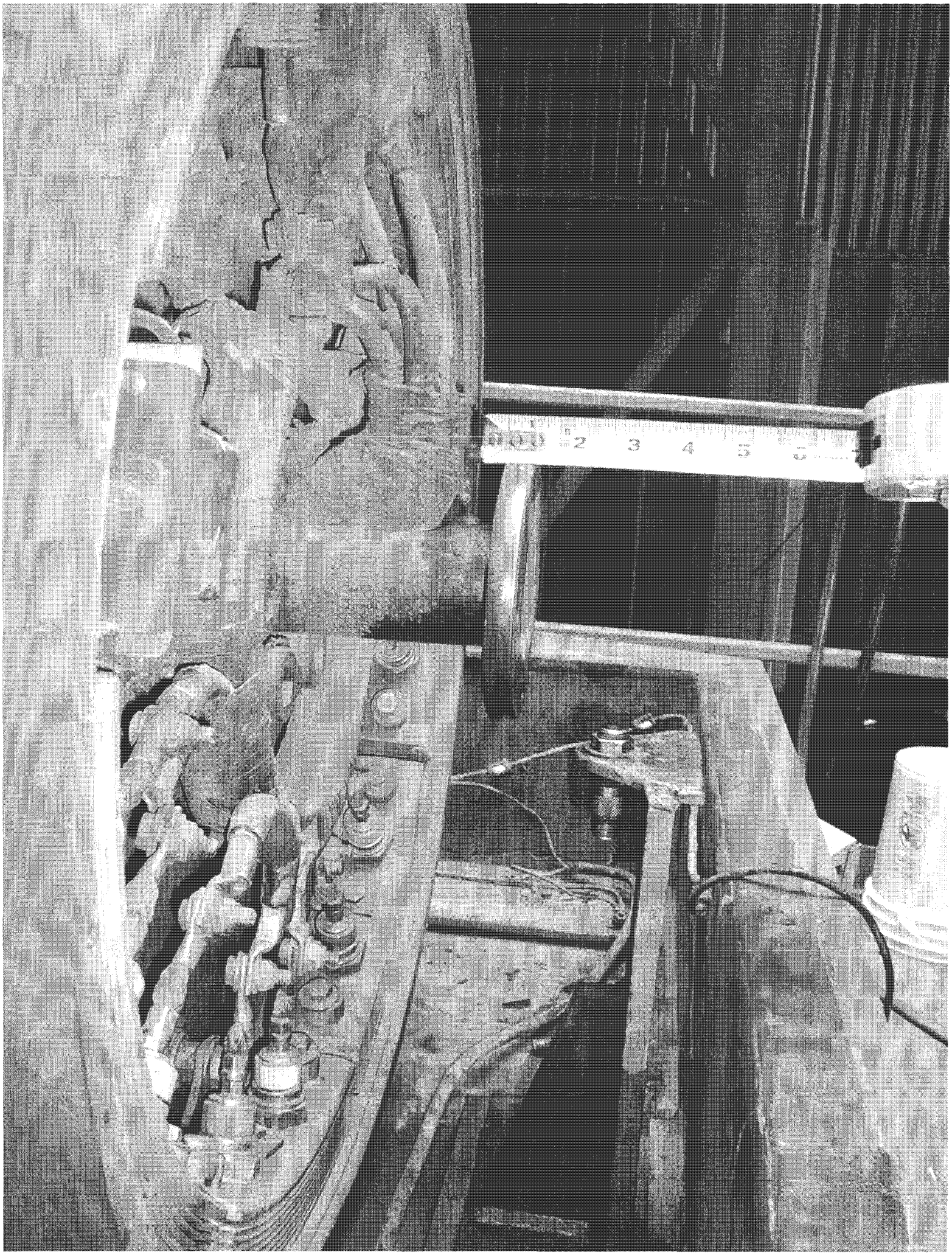
IP7015173



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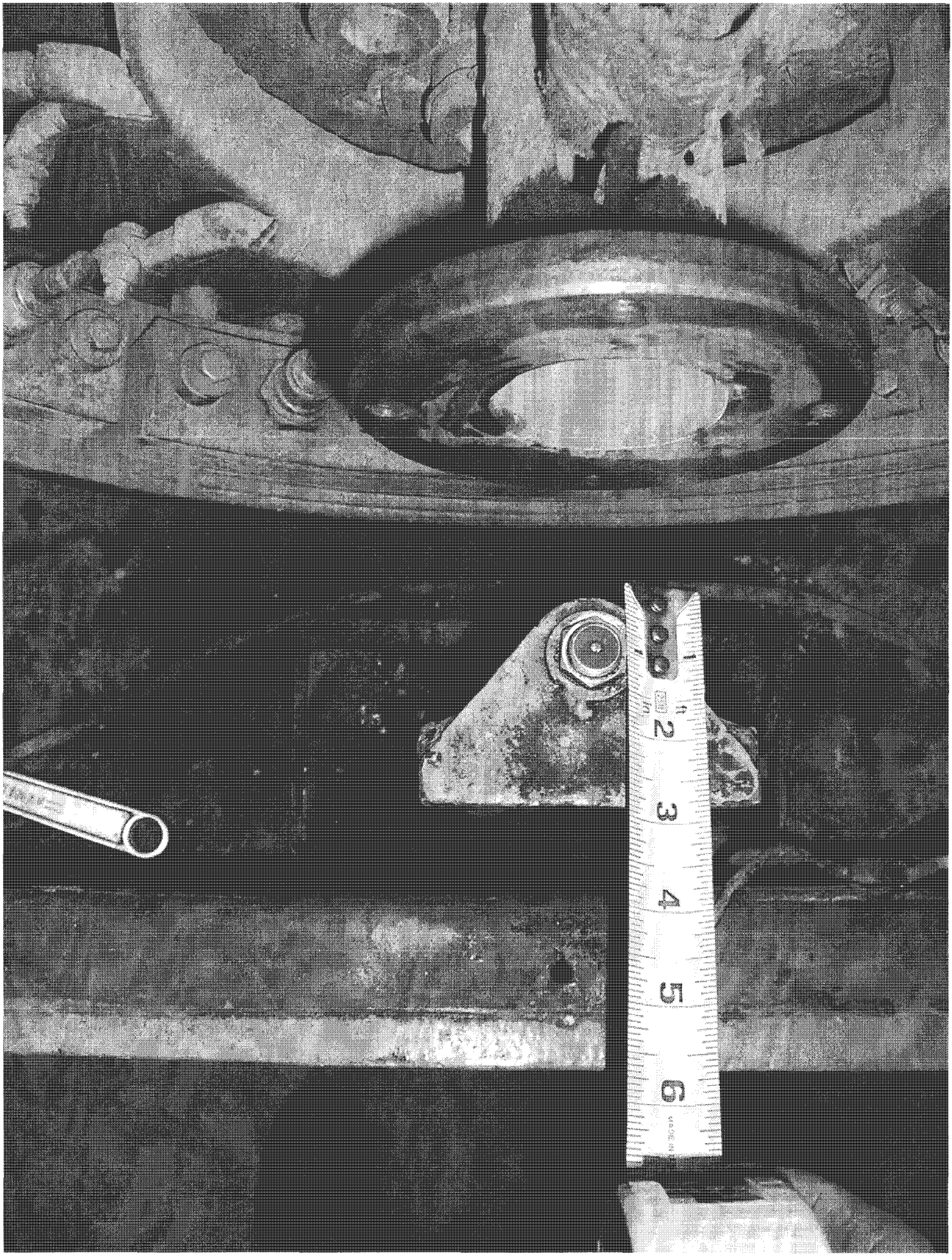

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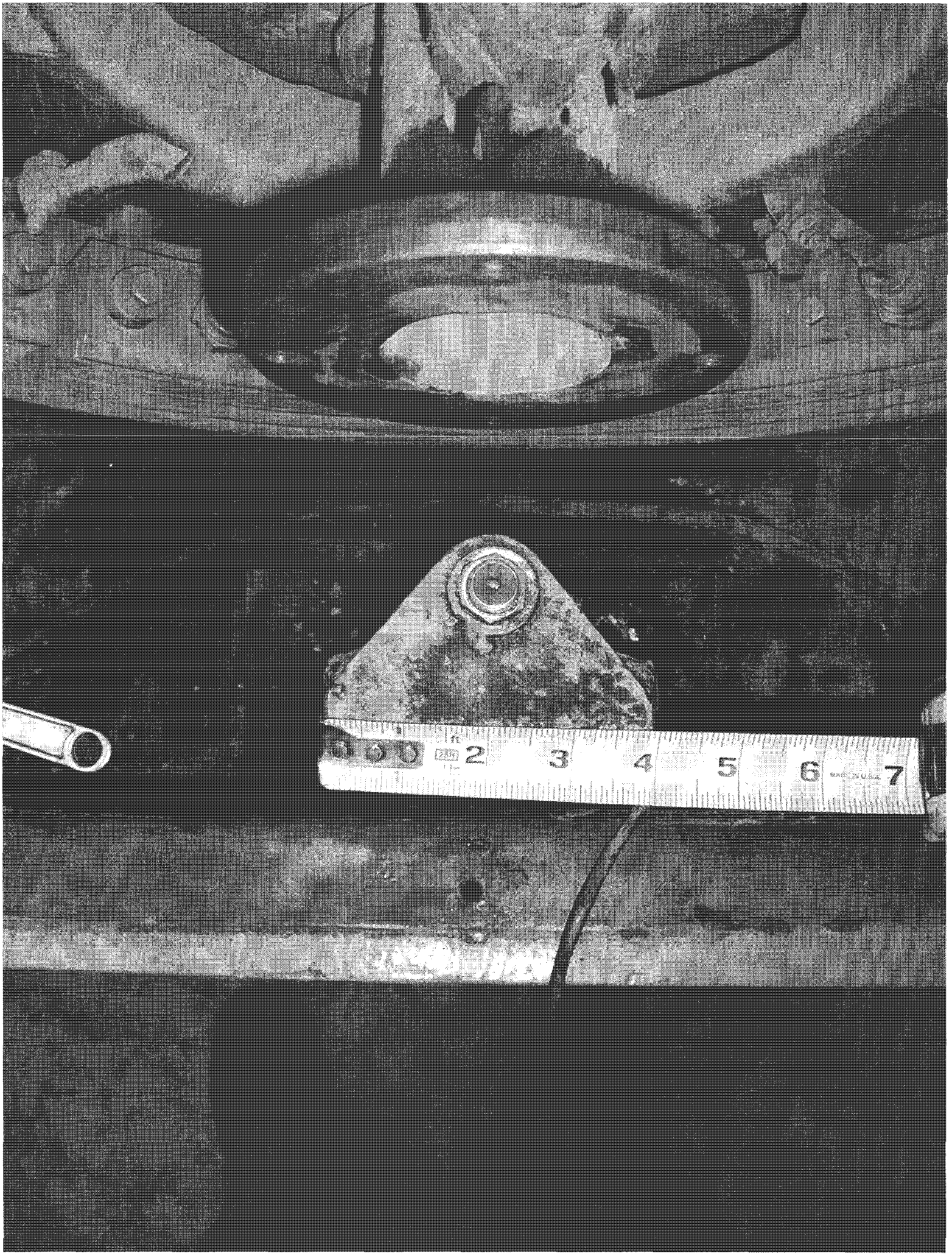

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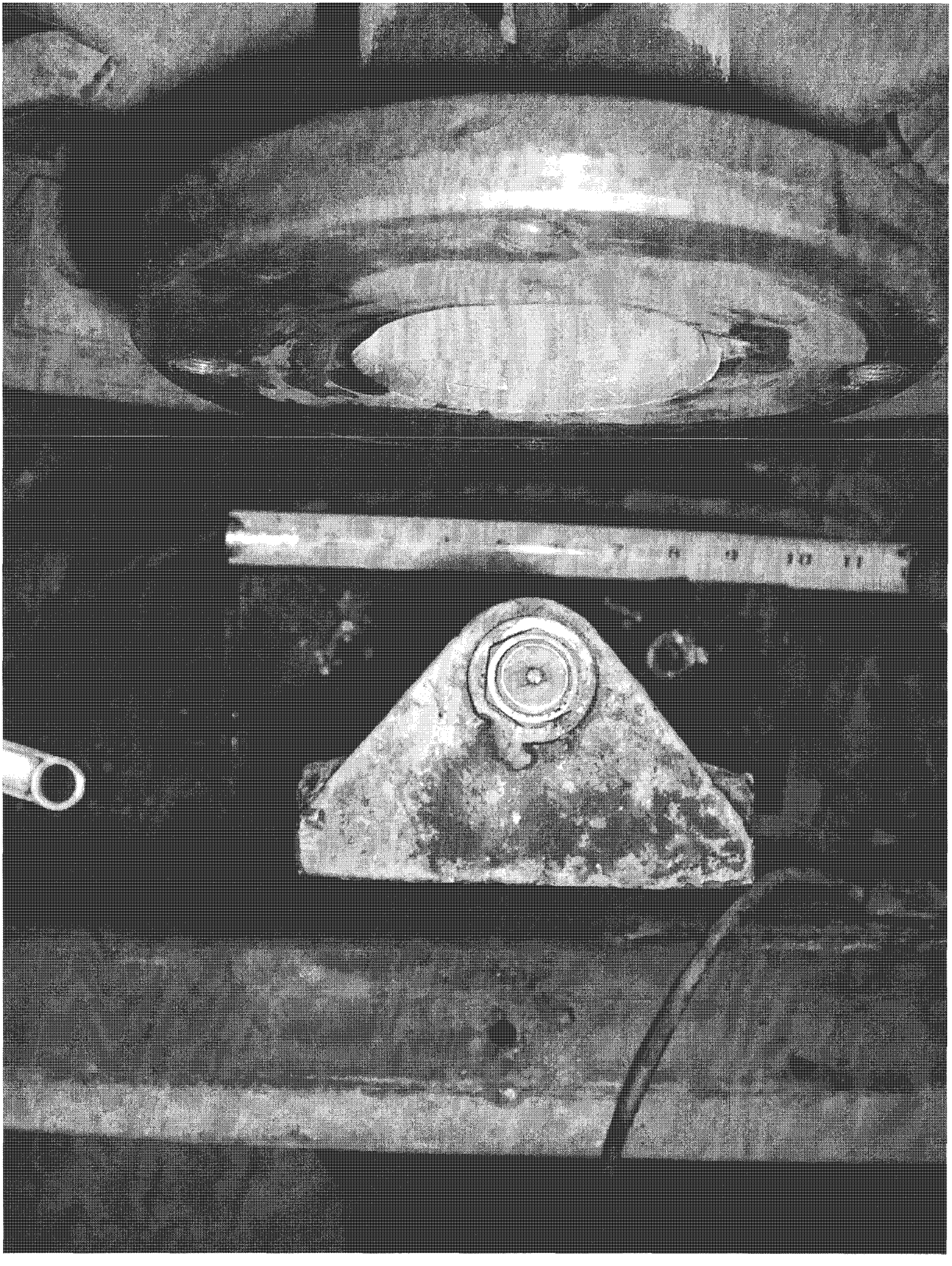

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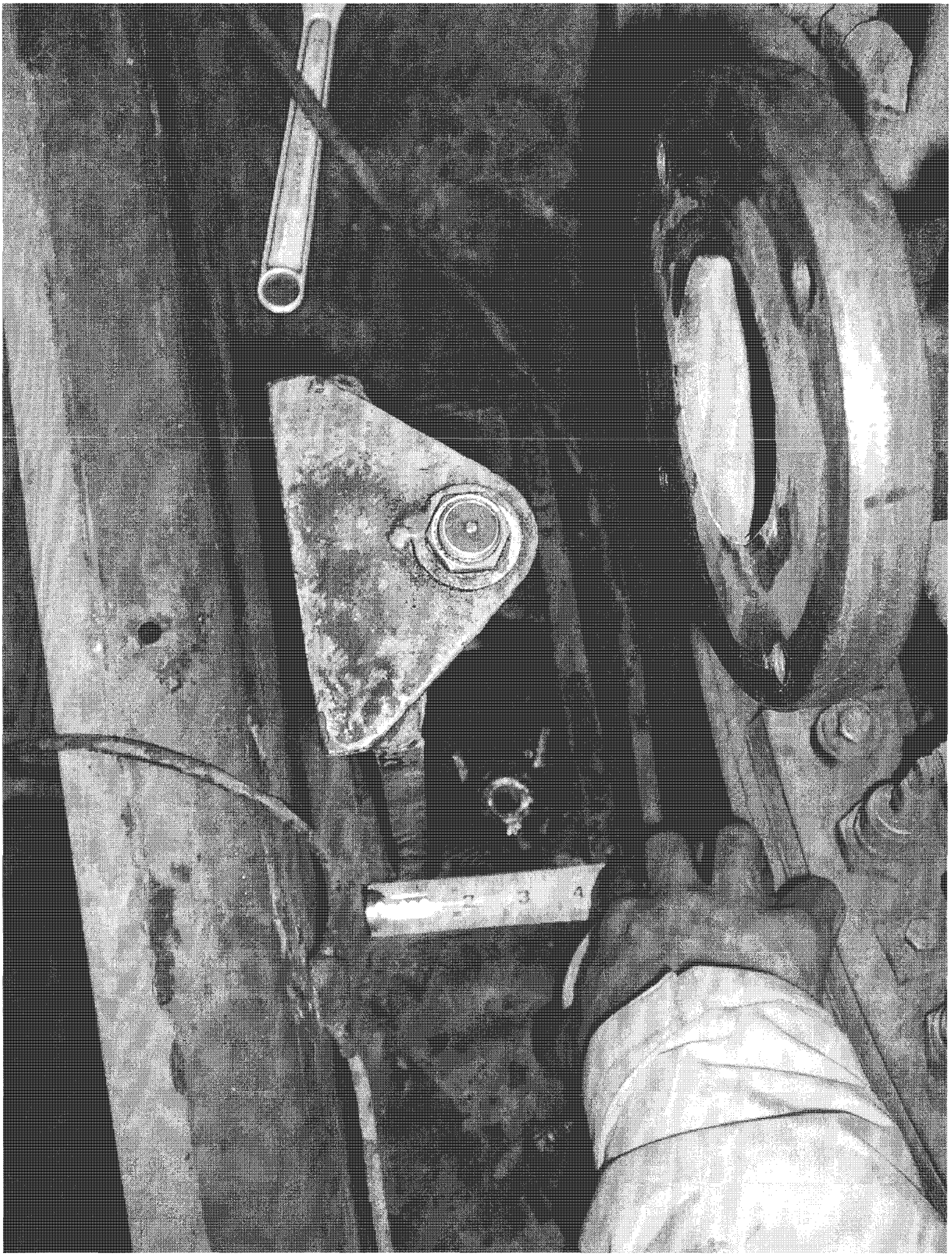

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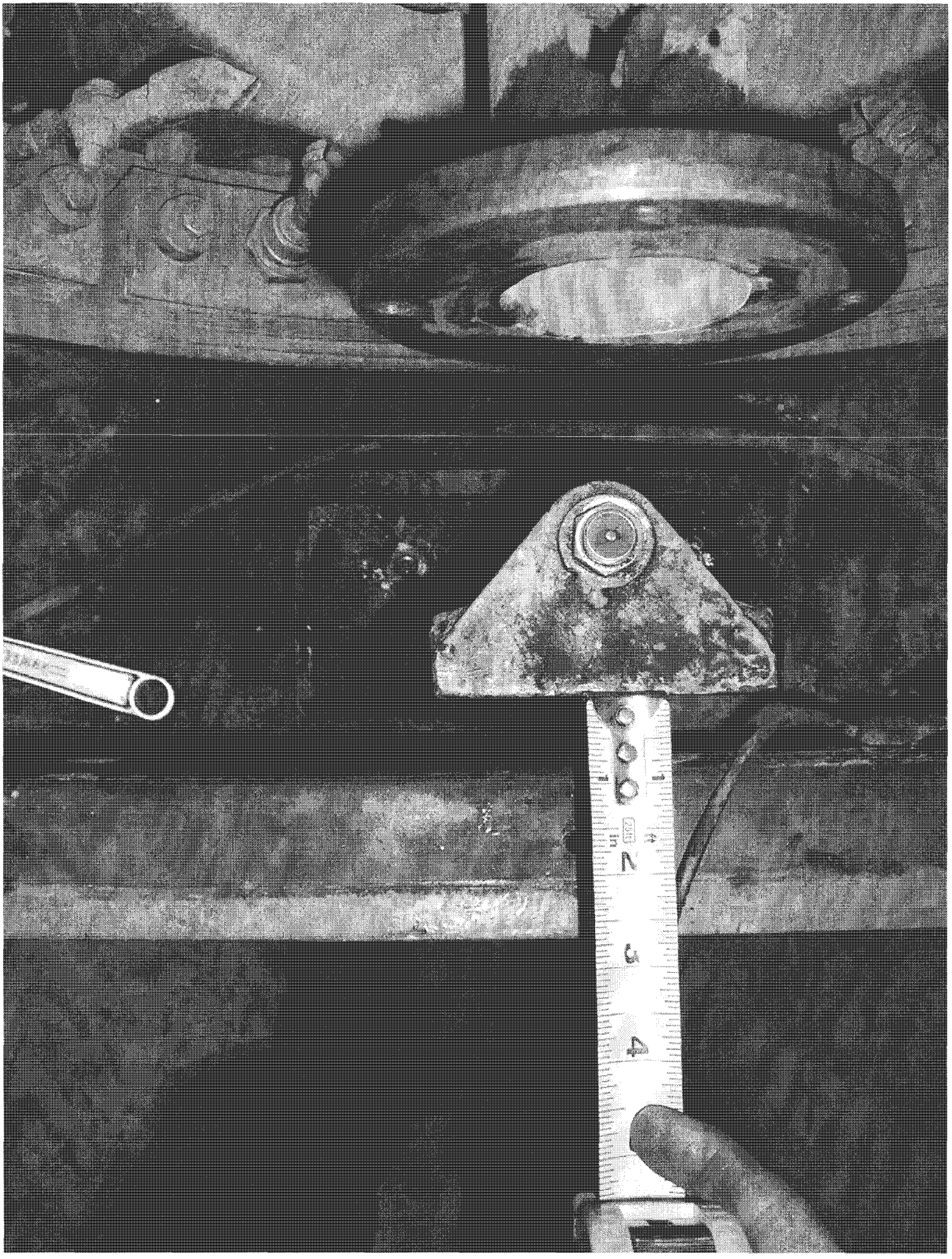

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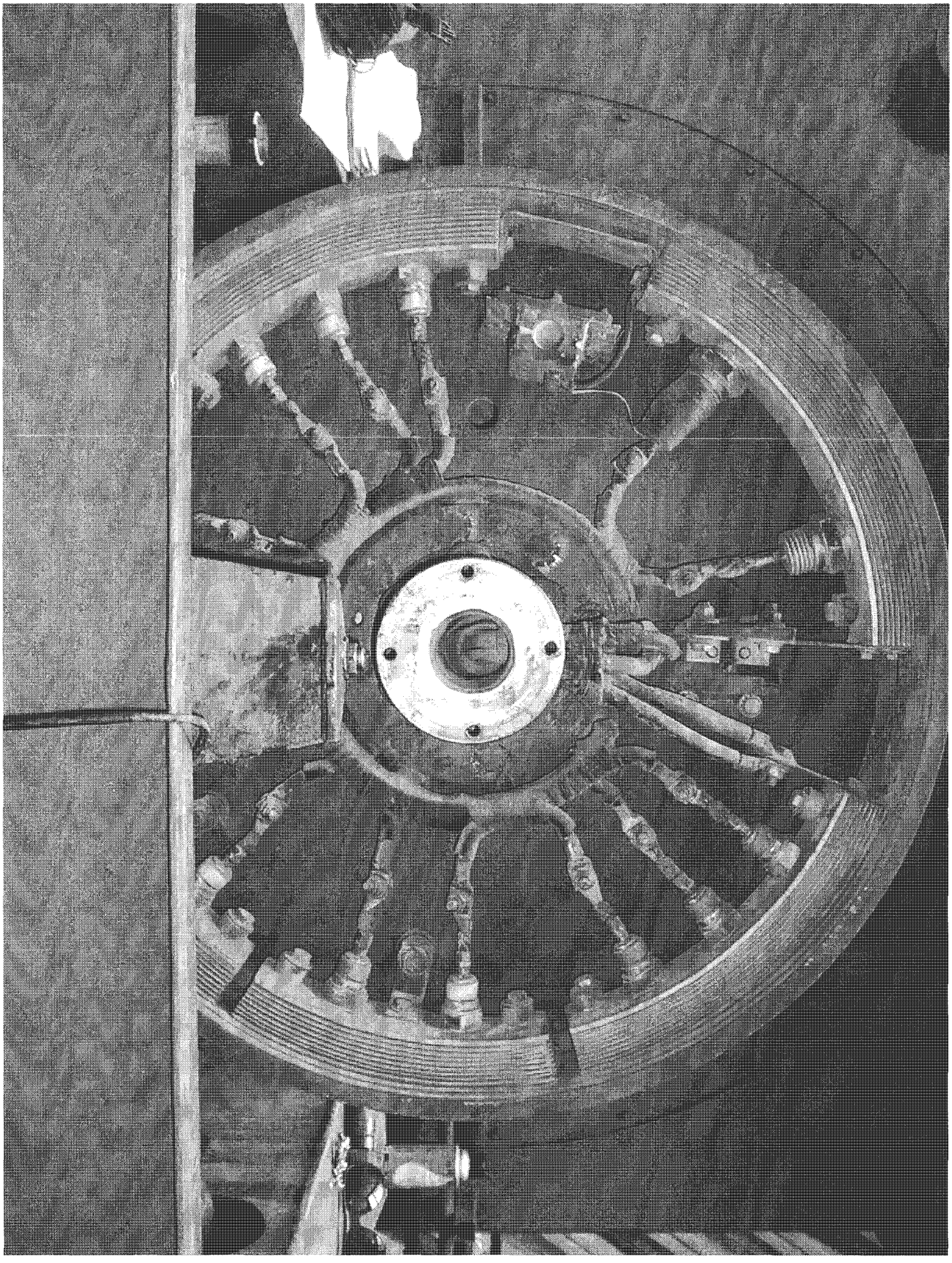

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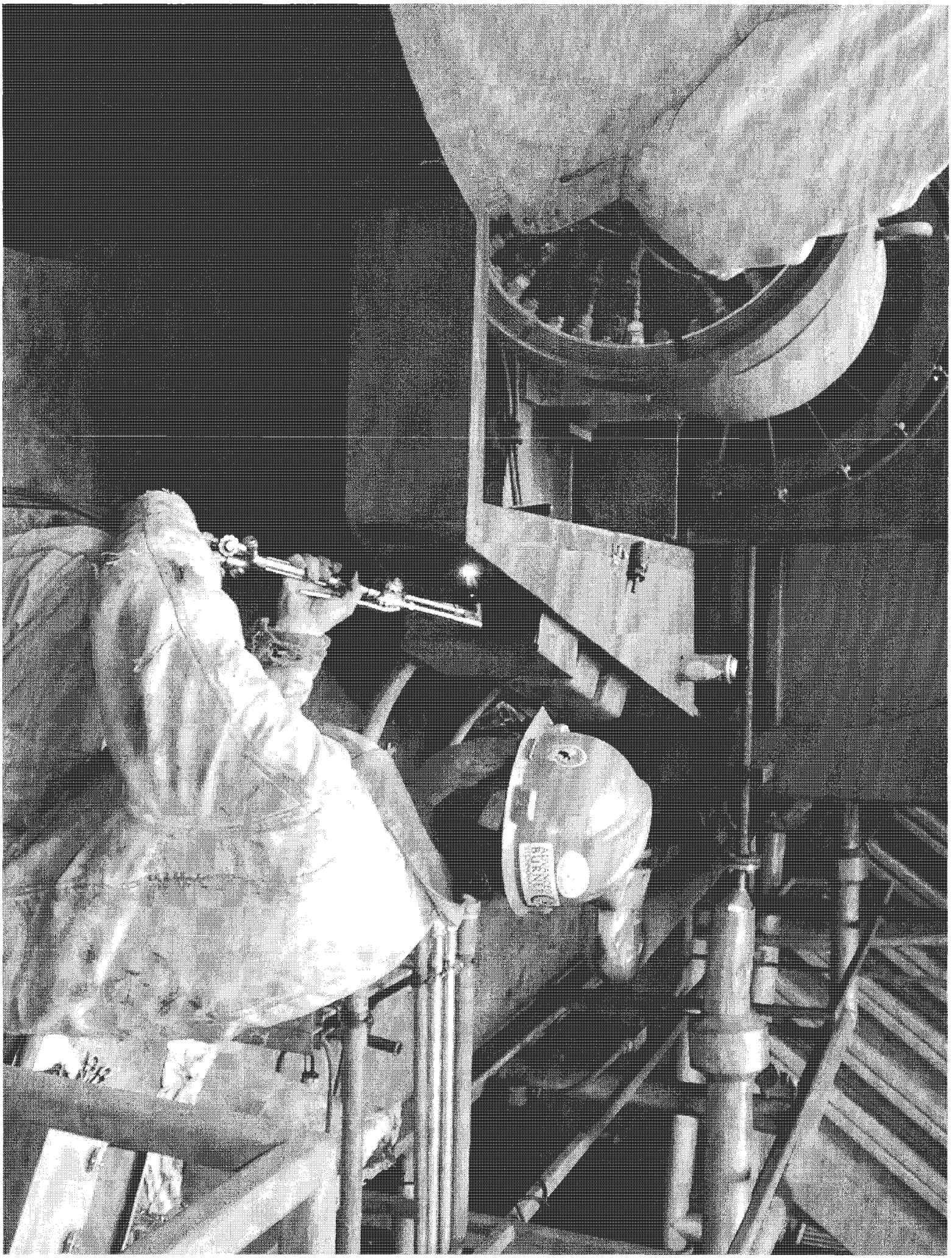

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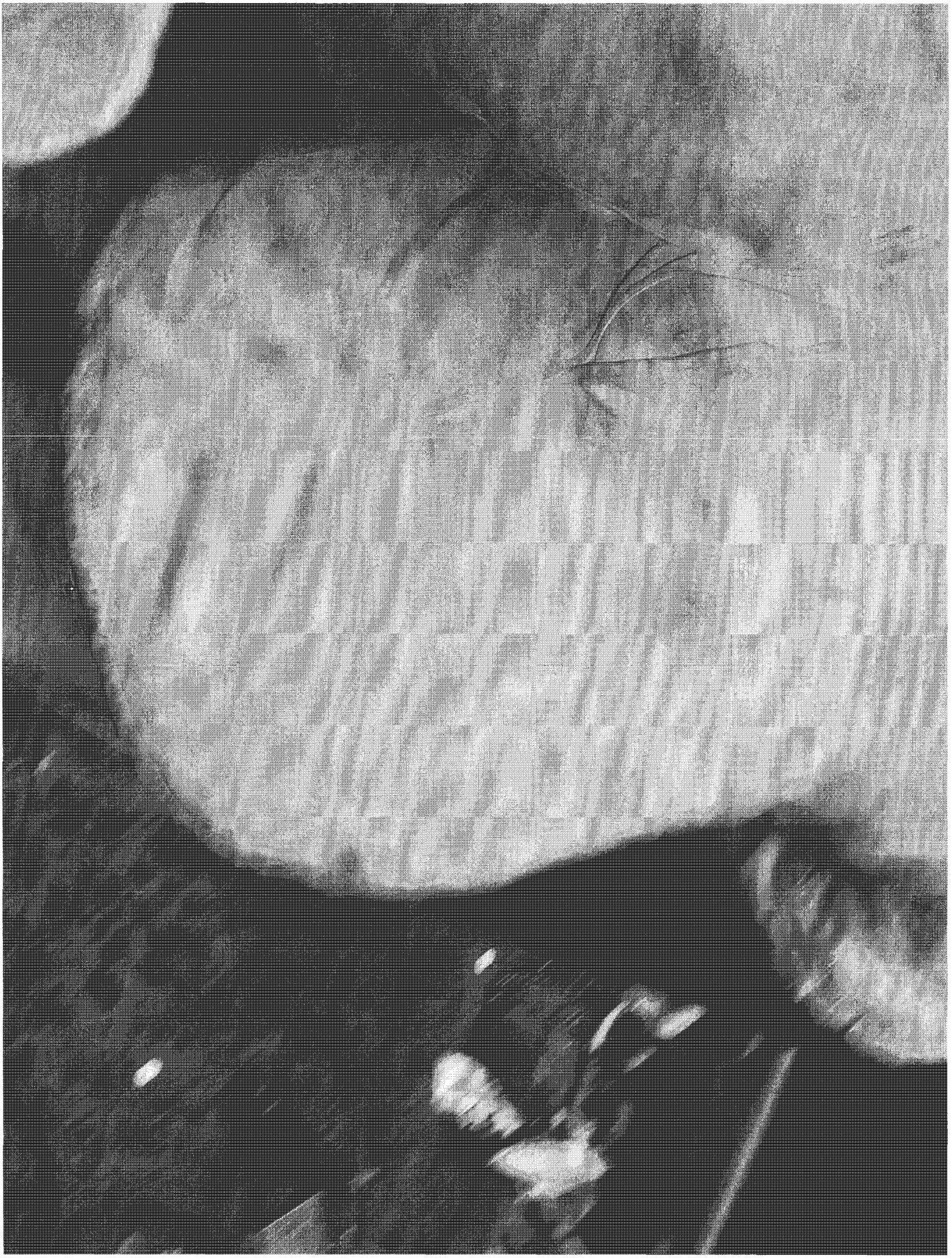

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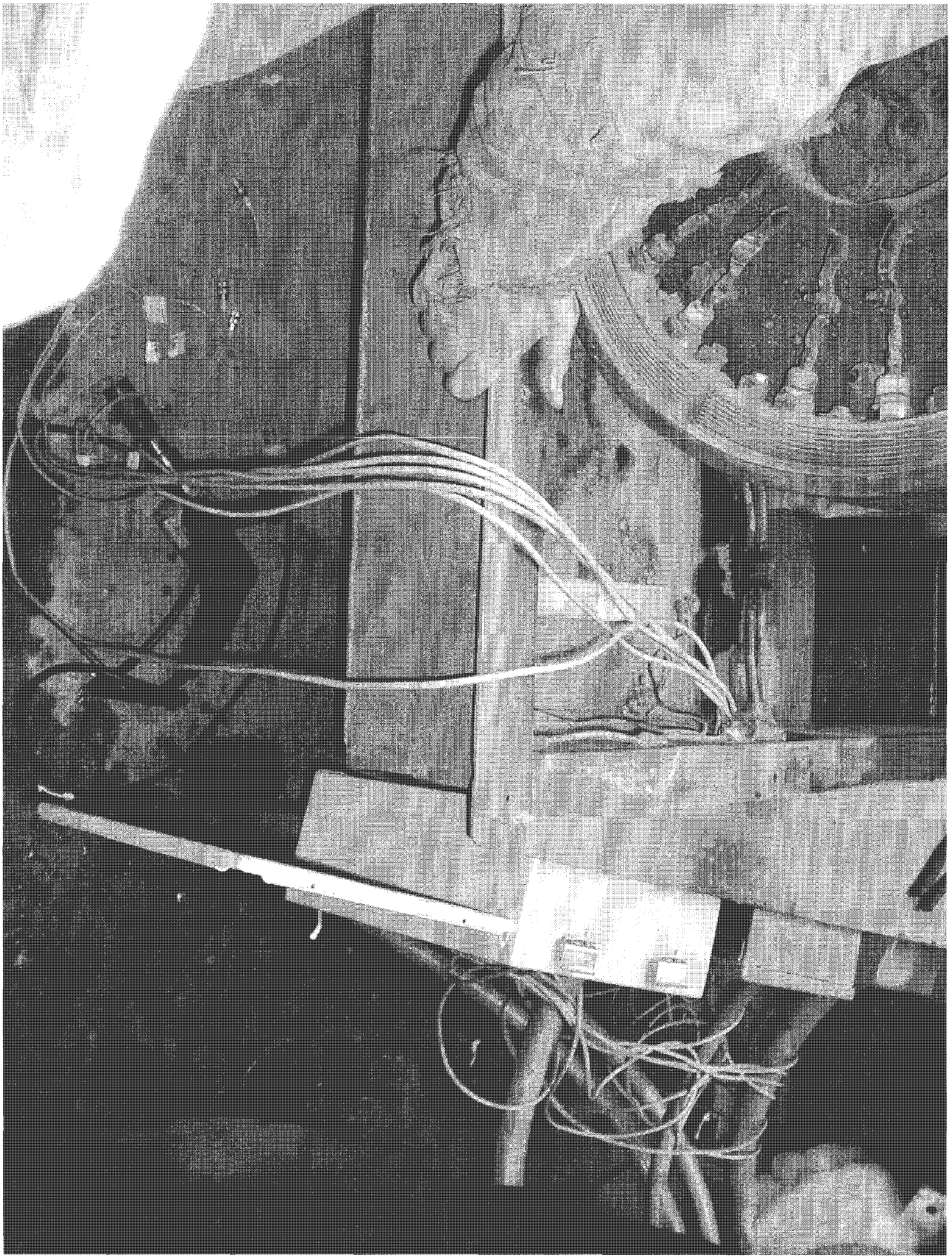

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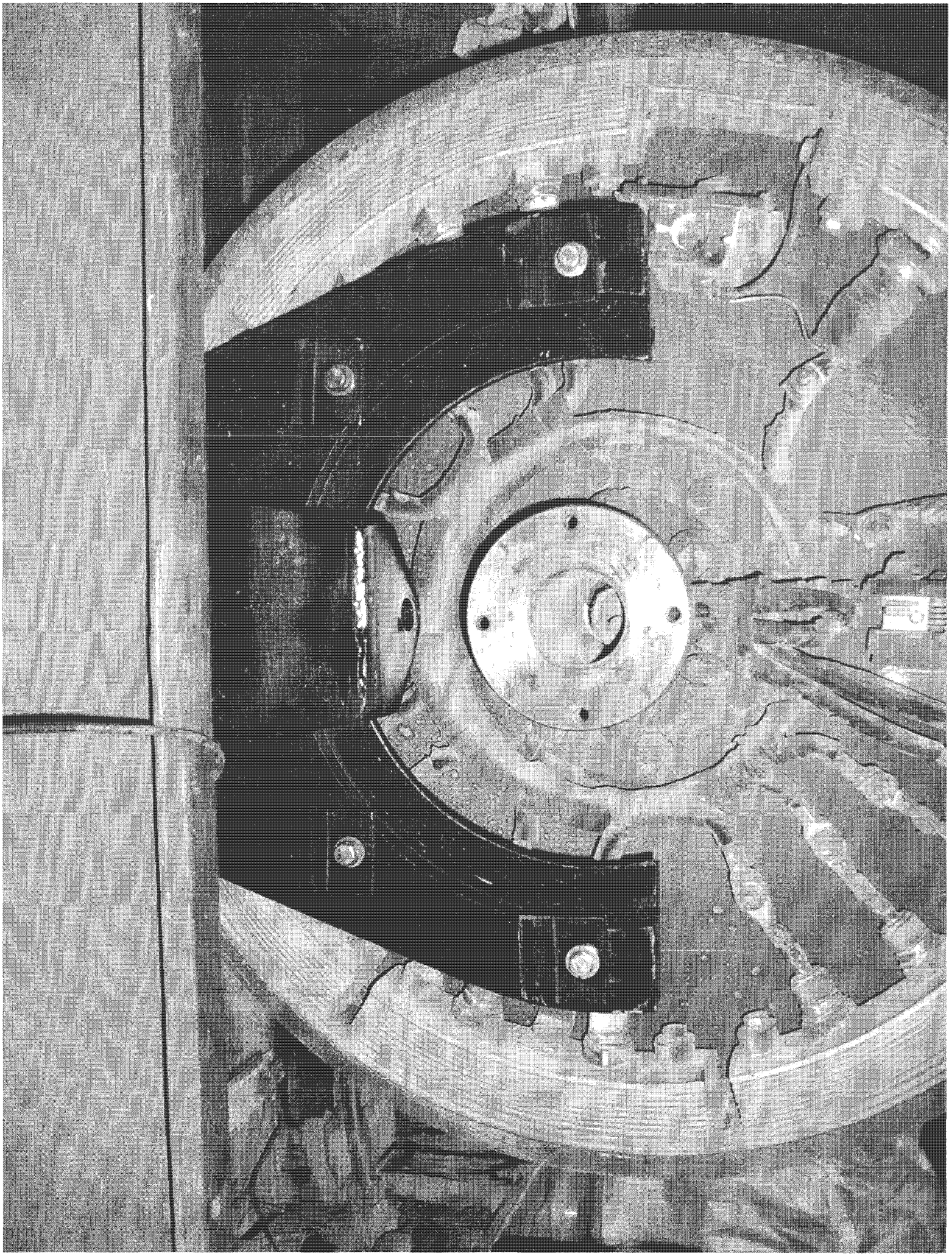

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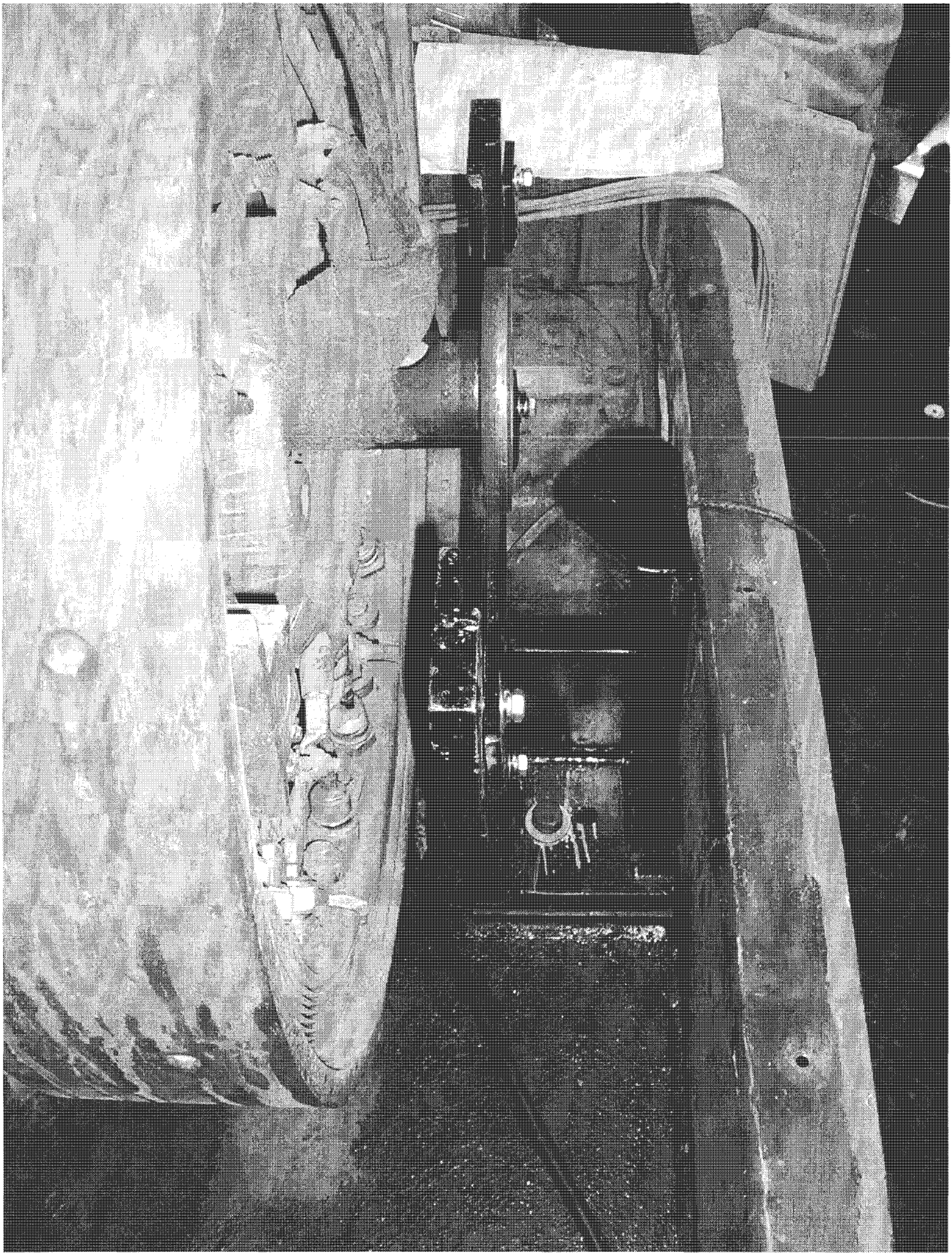

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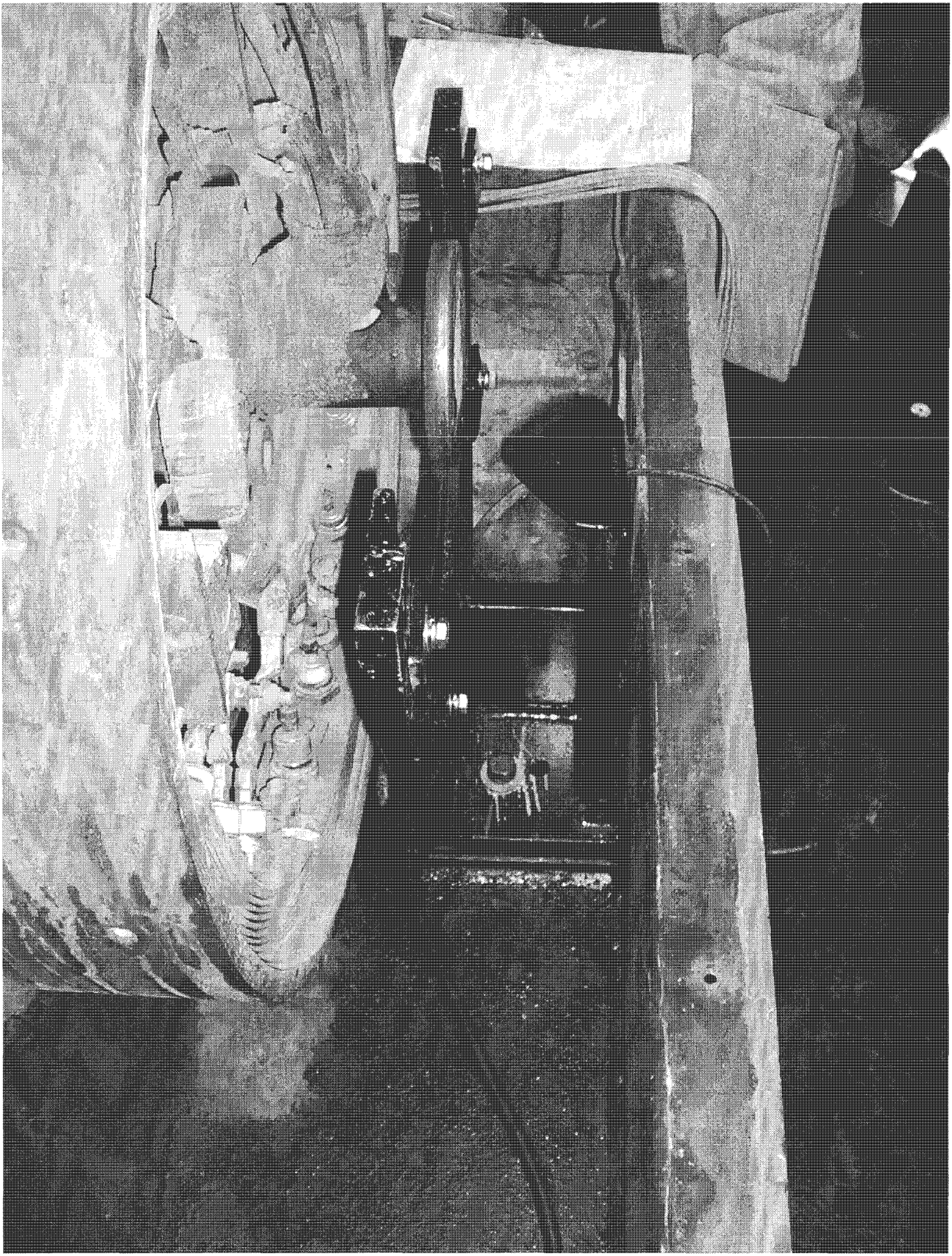

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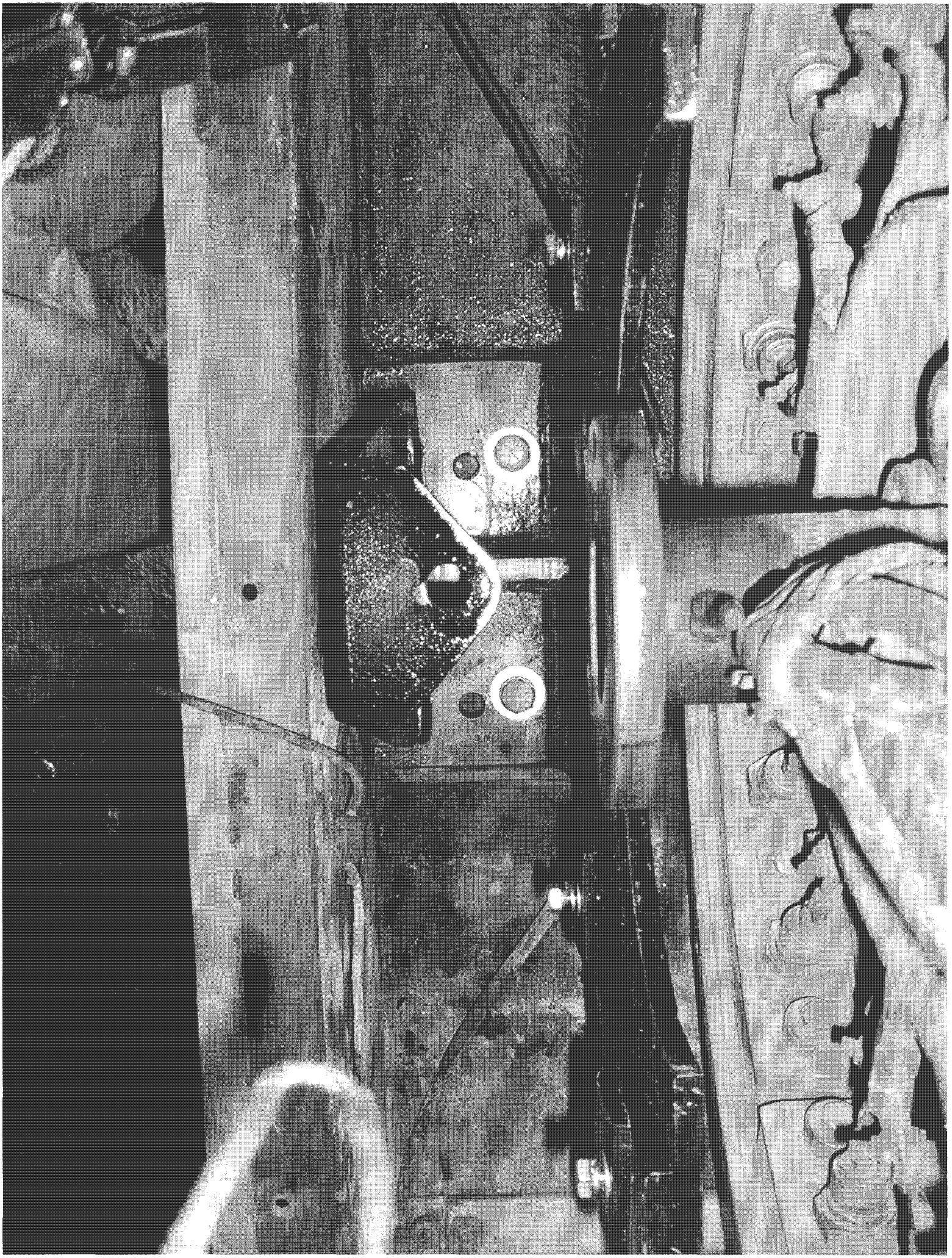

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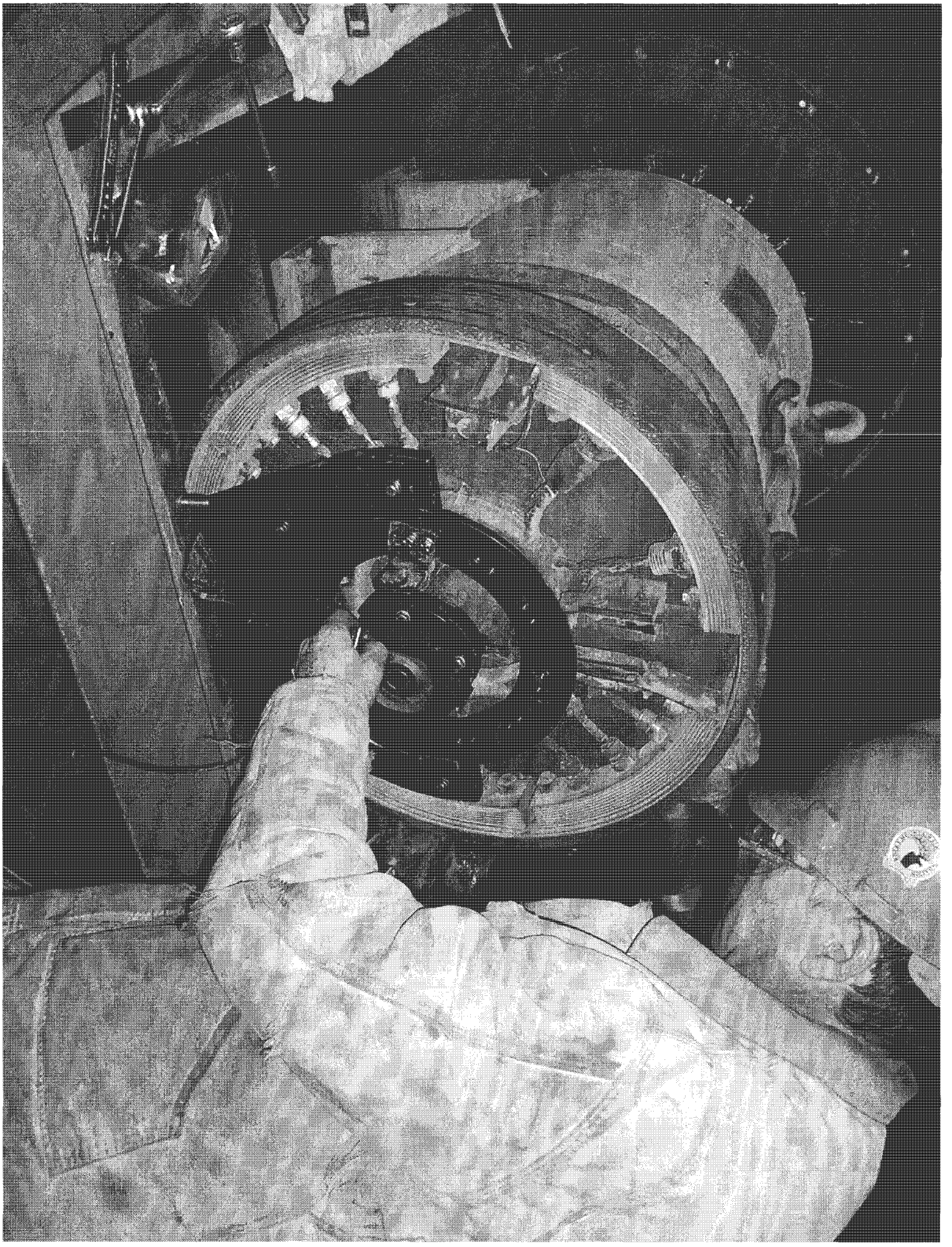

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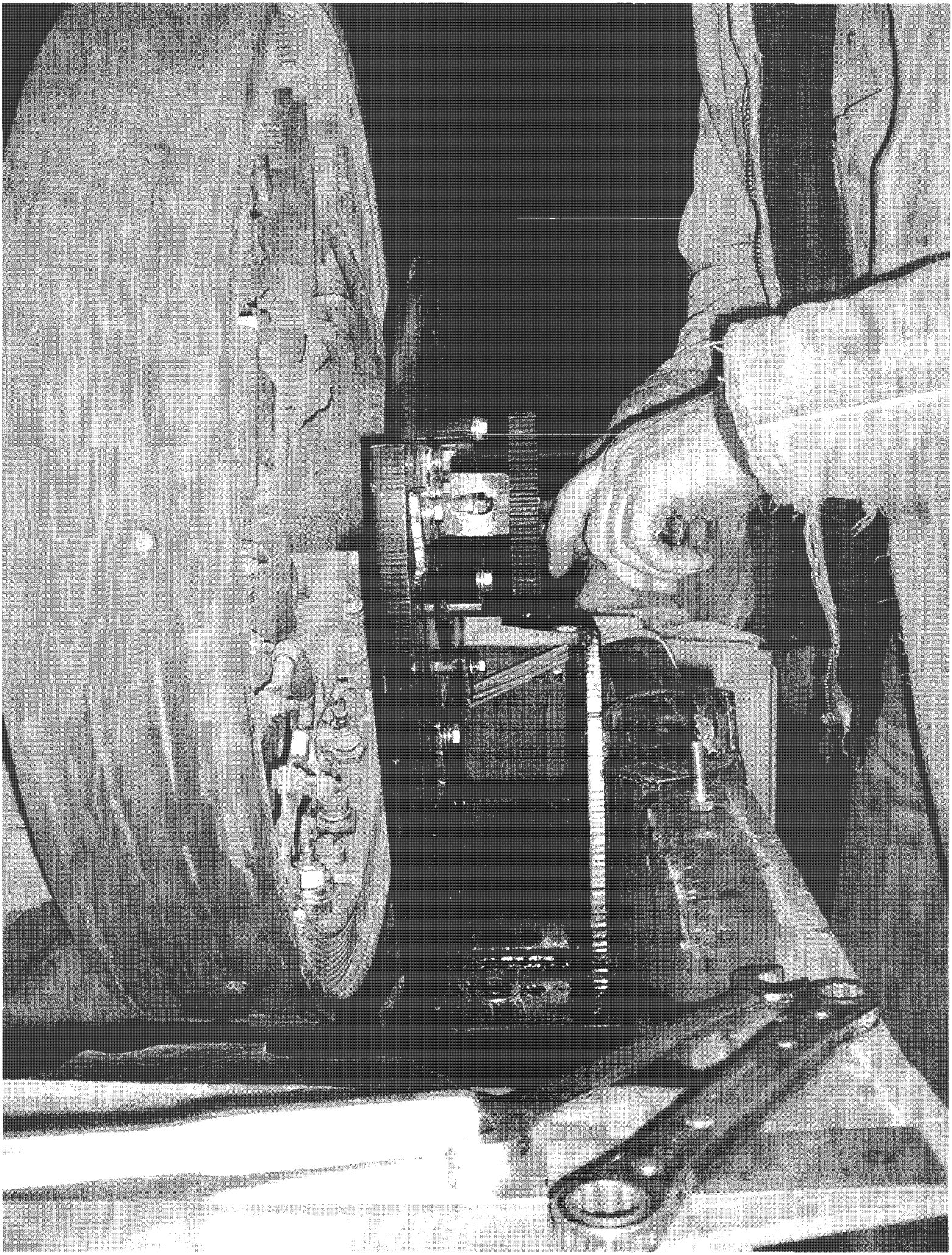

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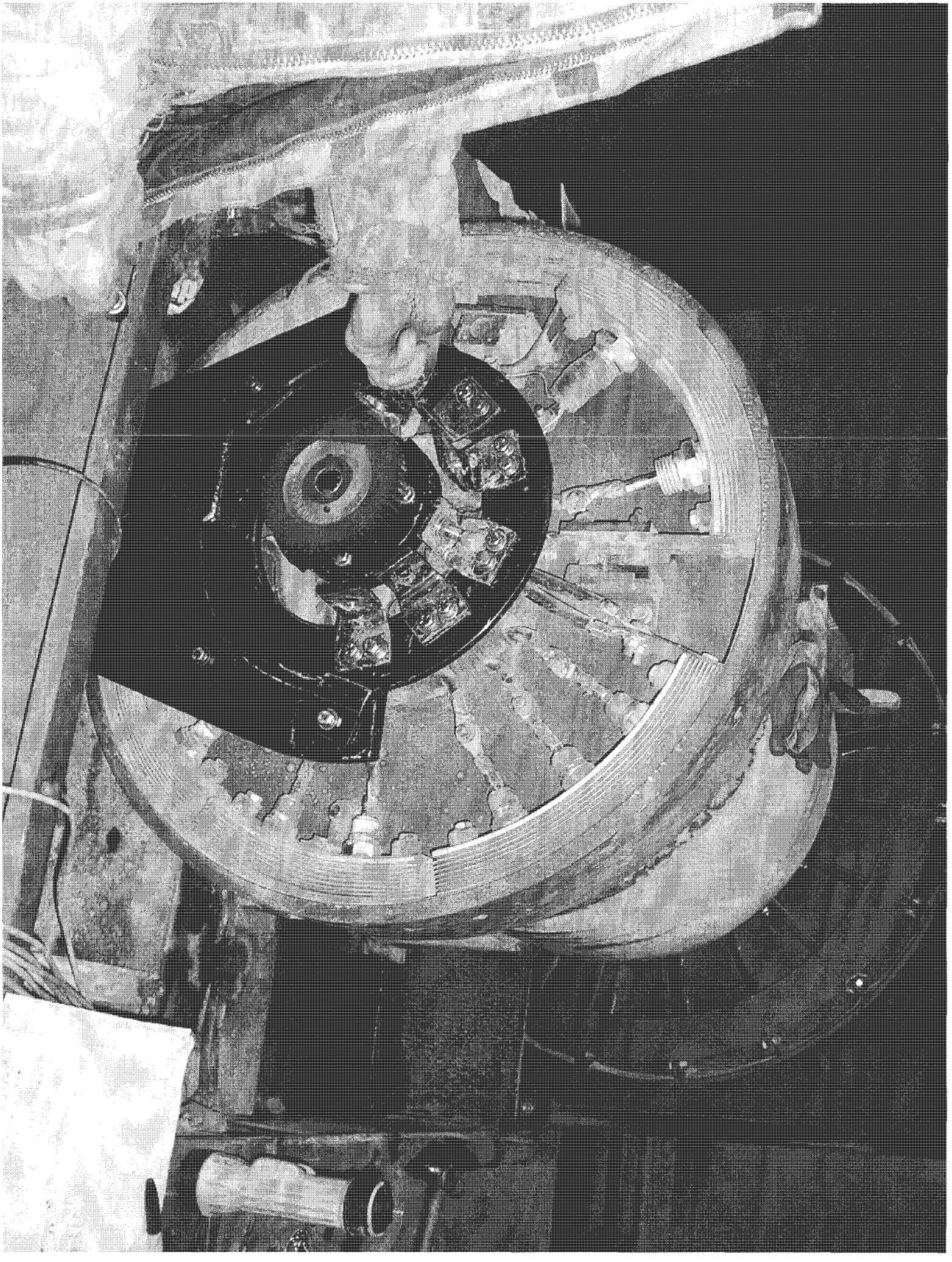

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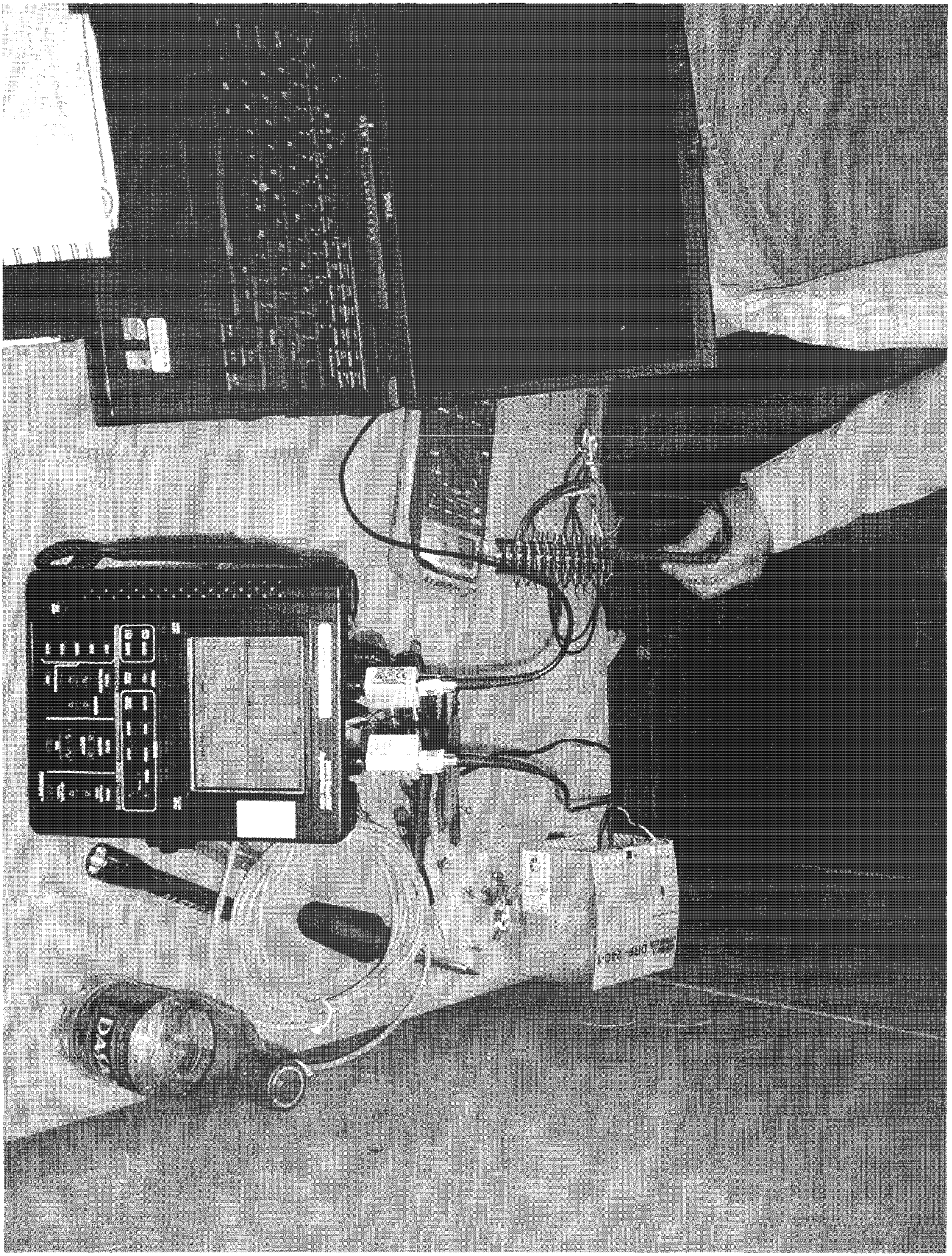

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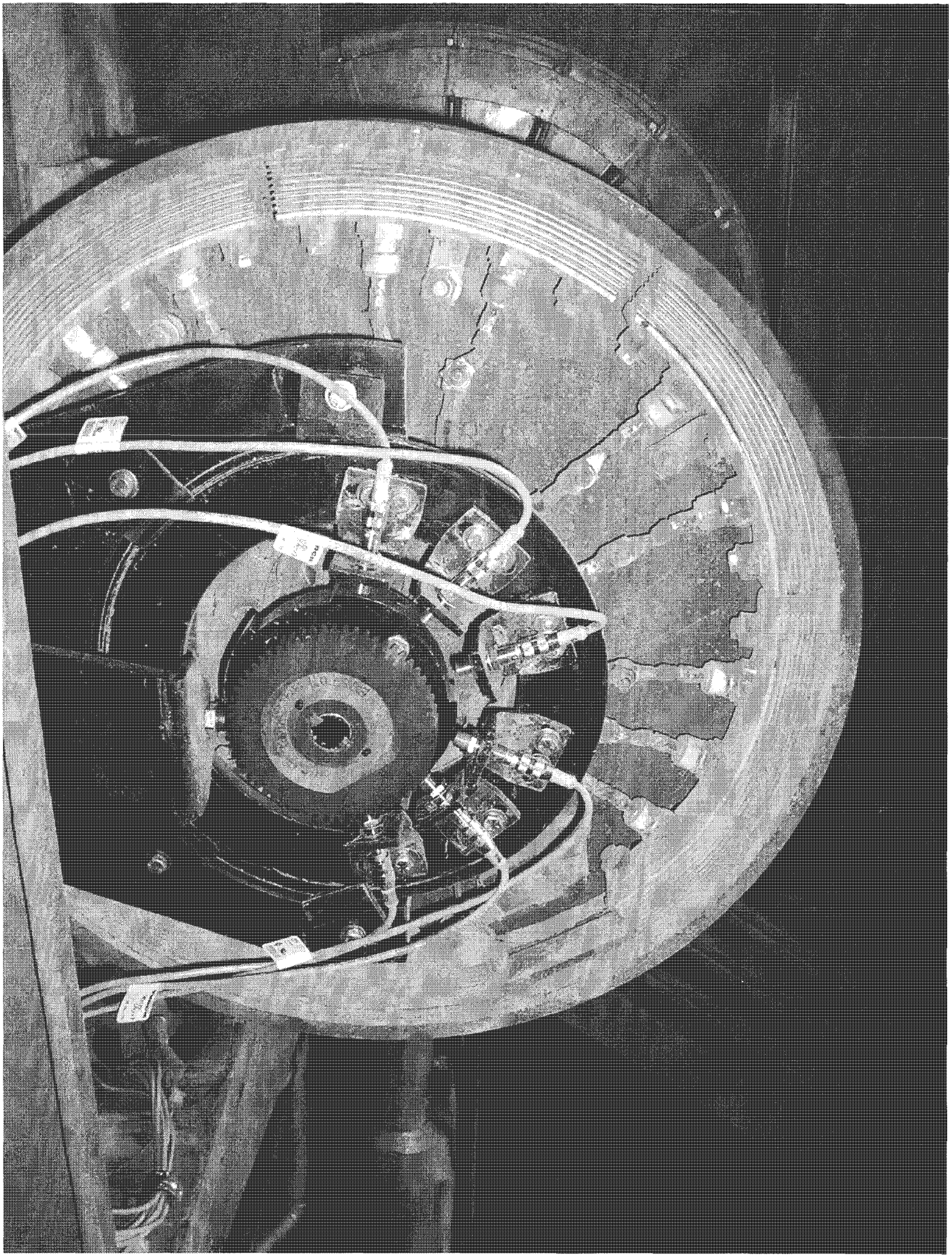

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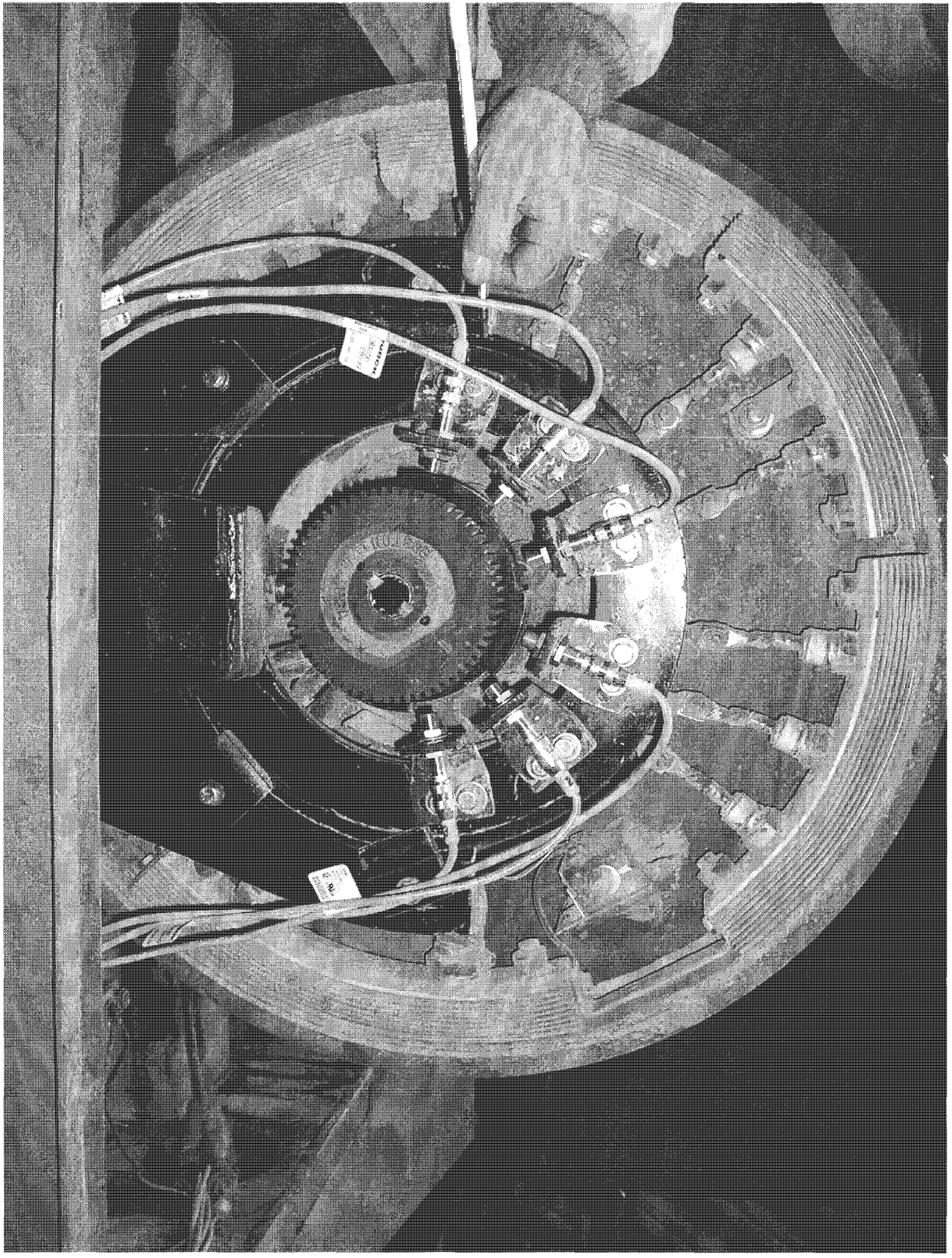

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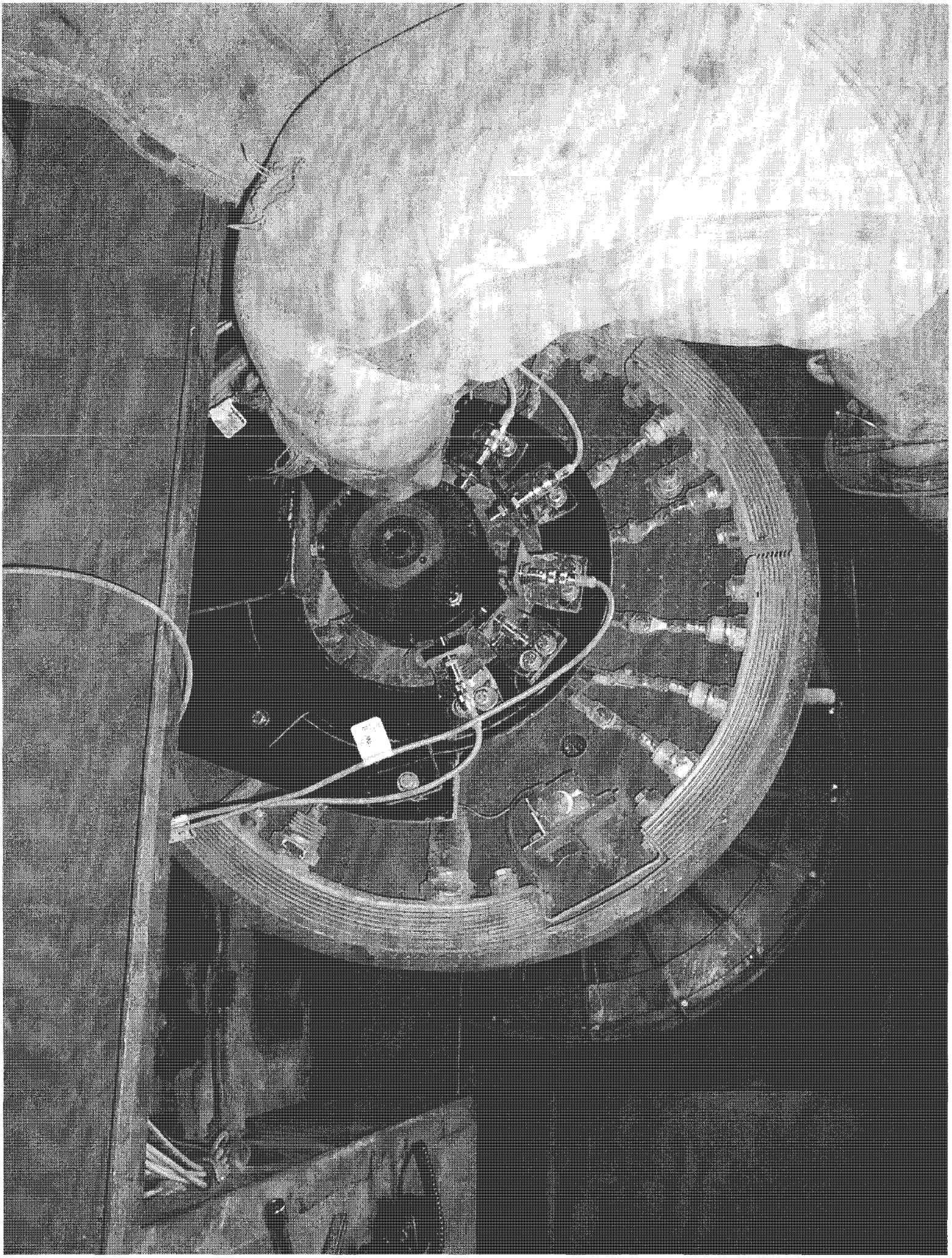

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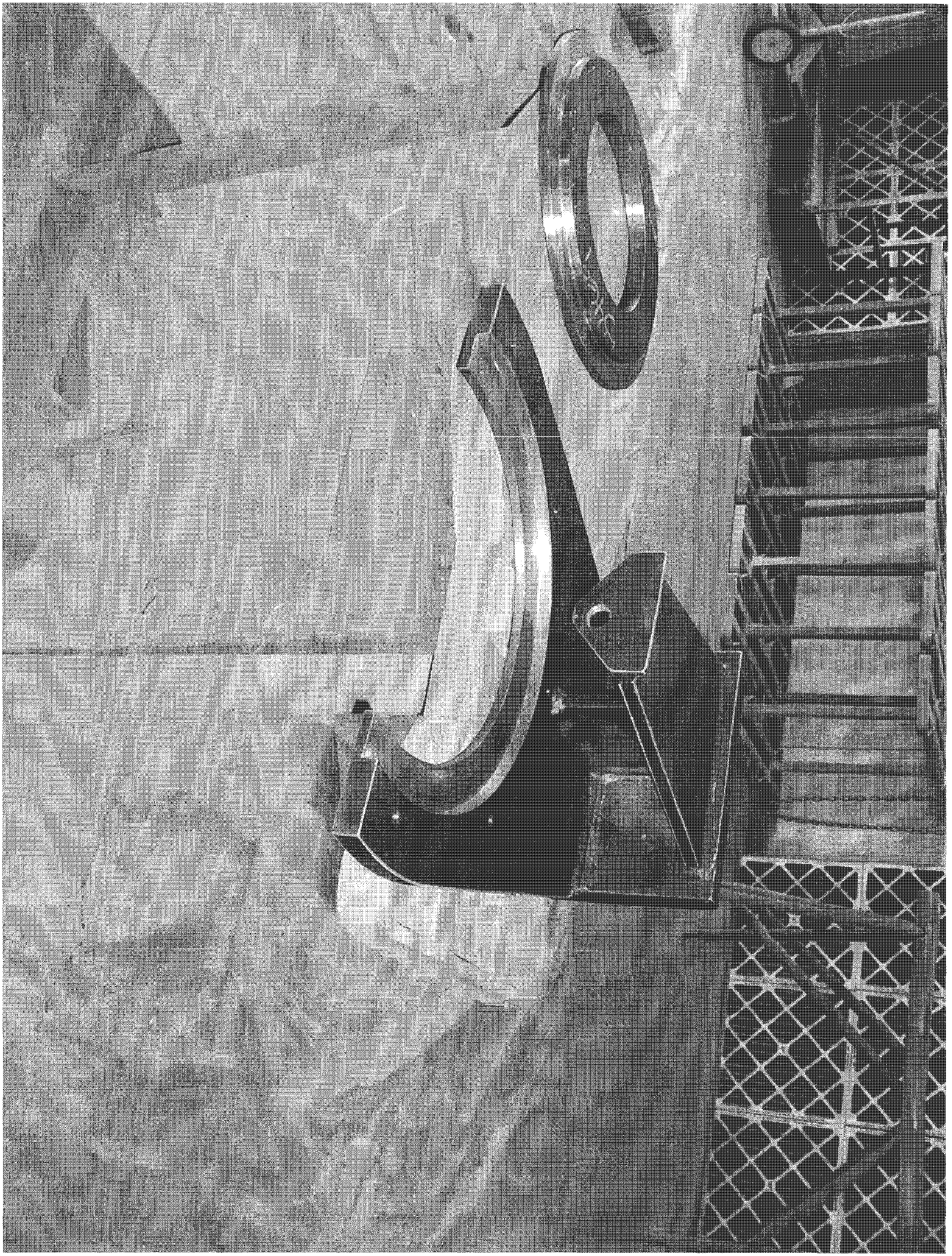

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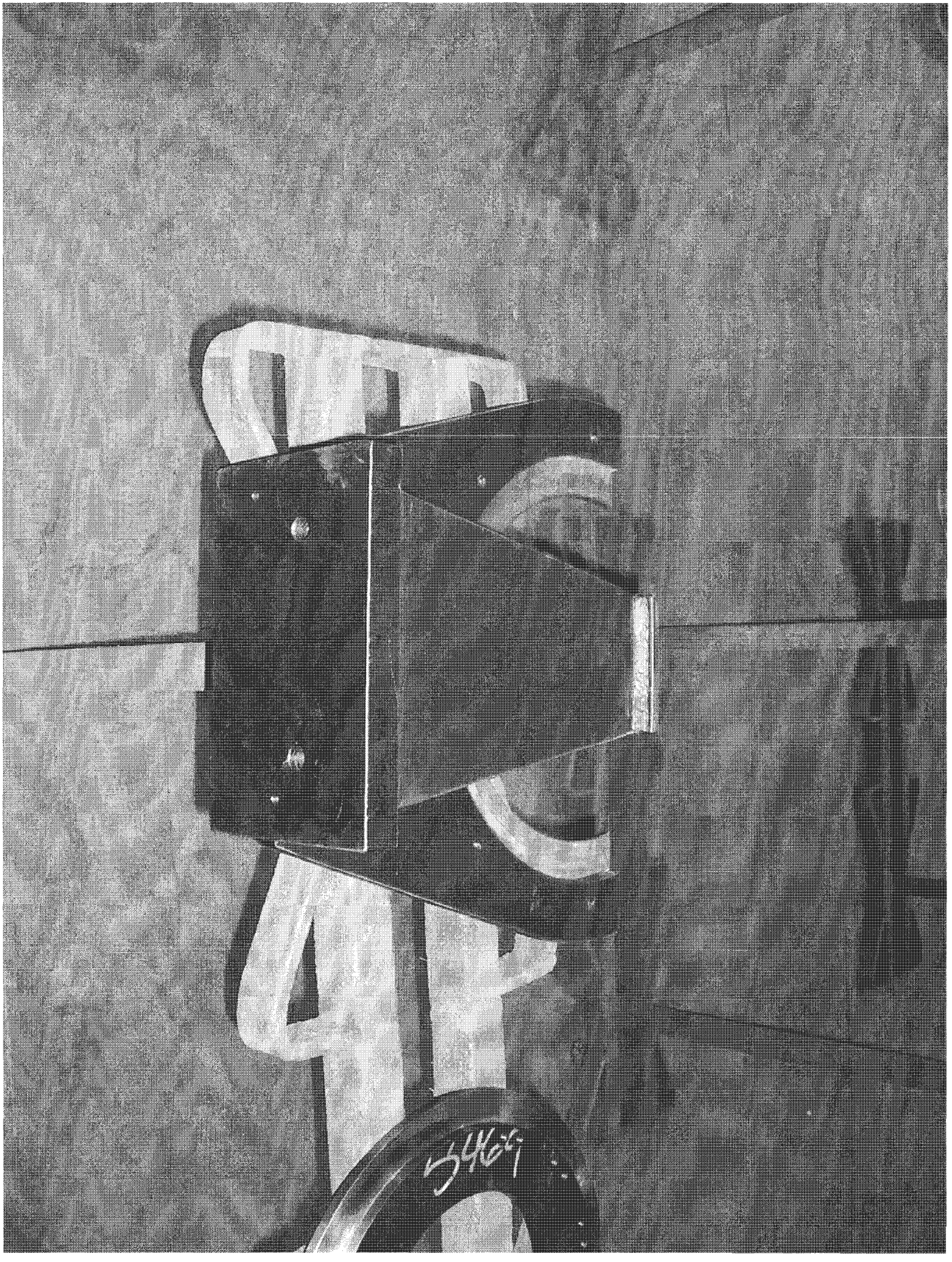

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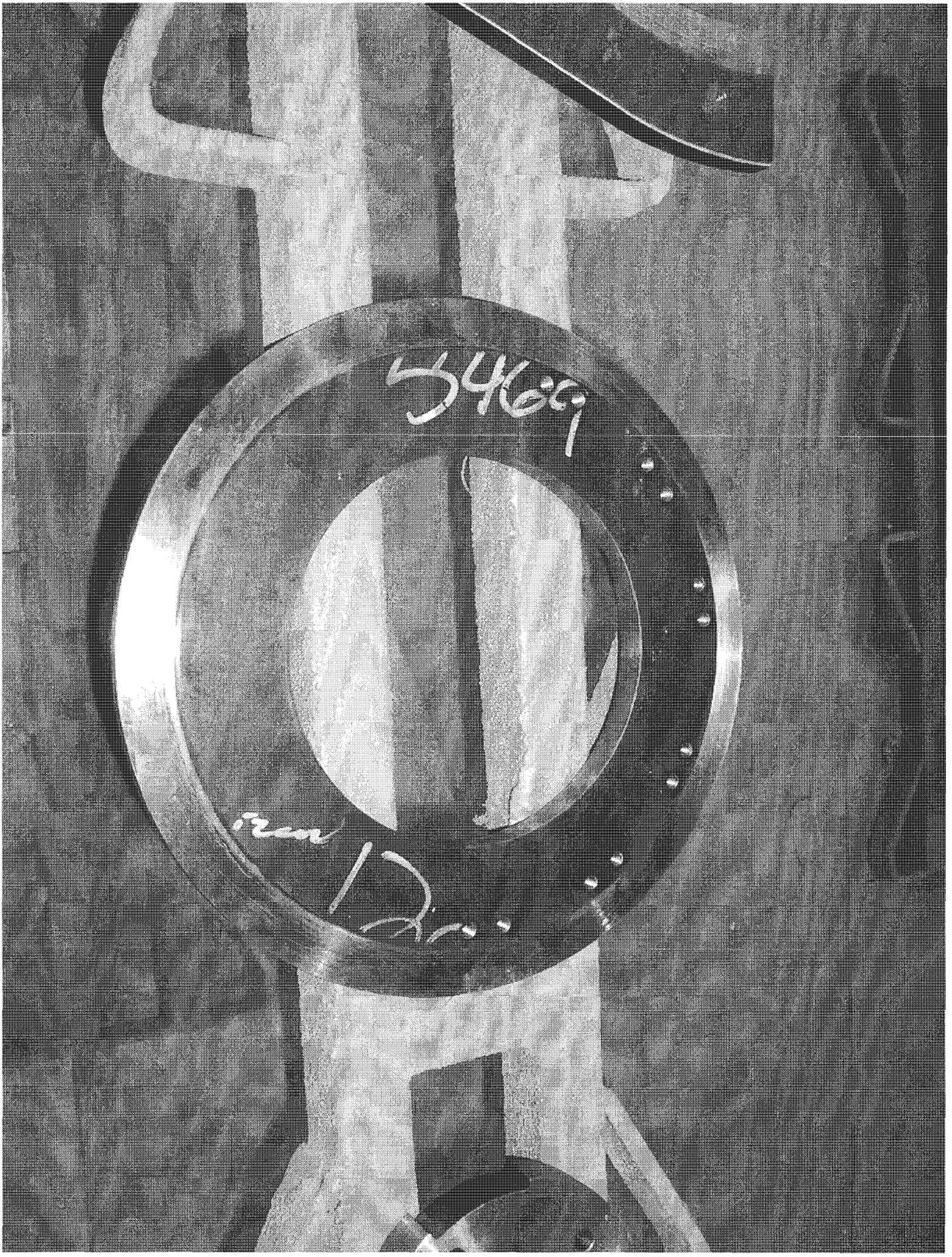

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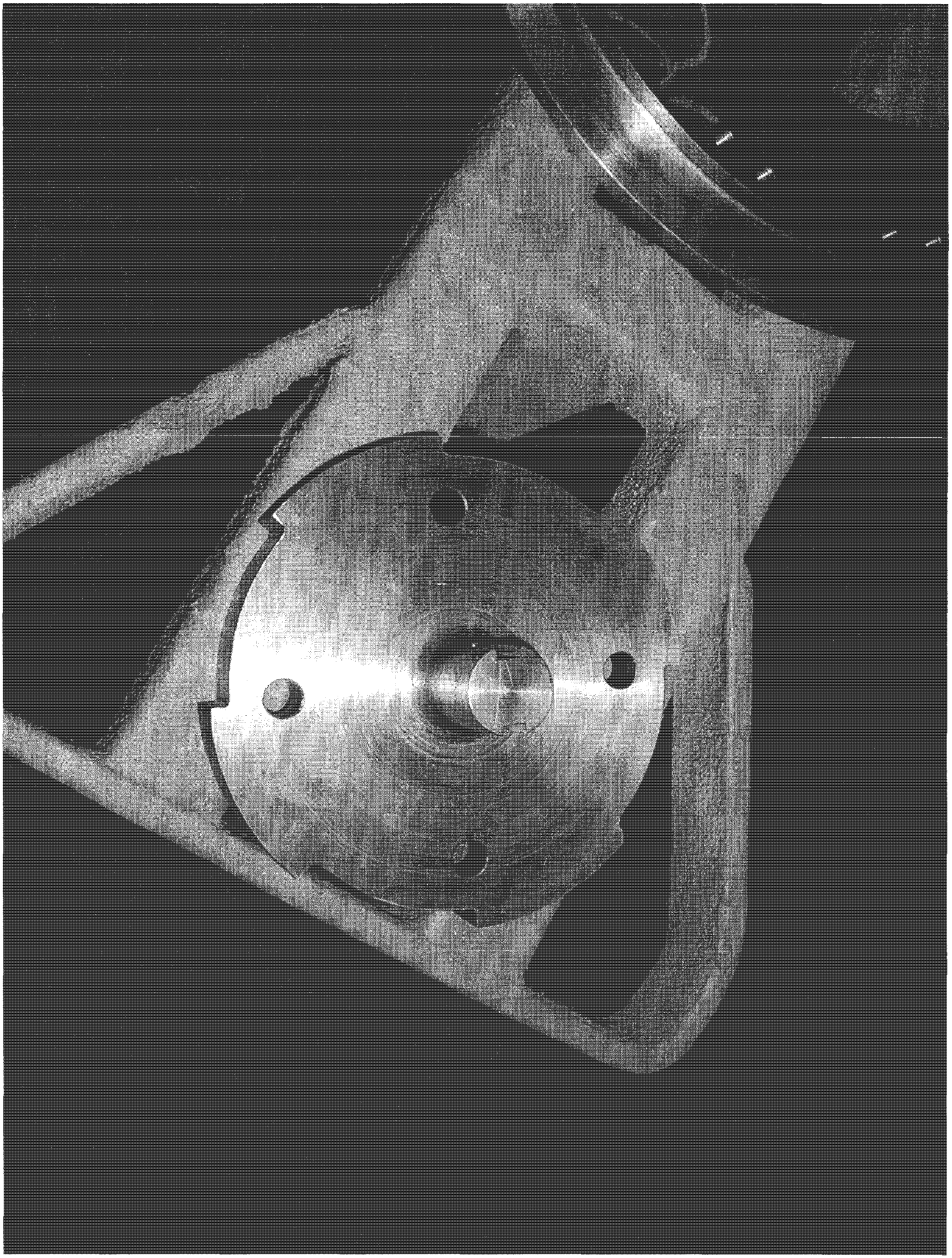

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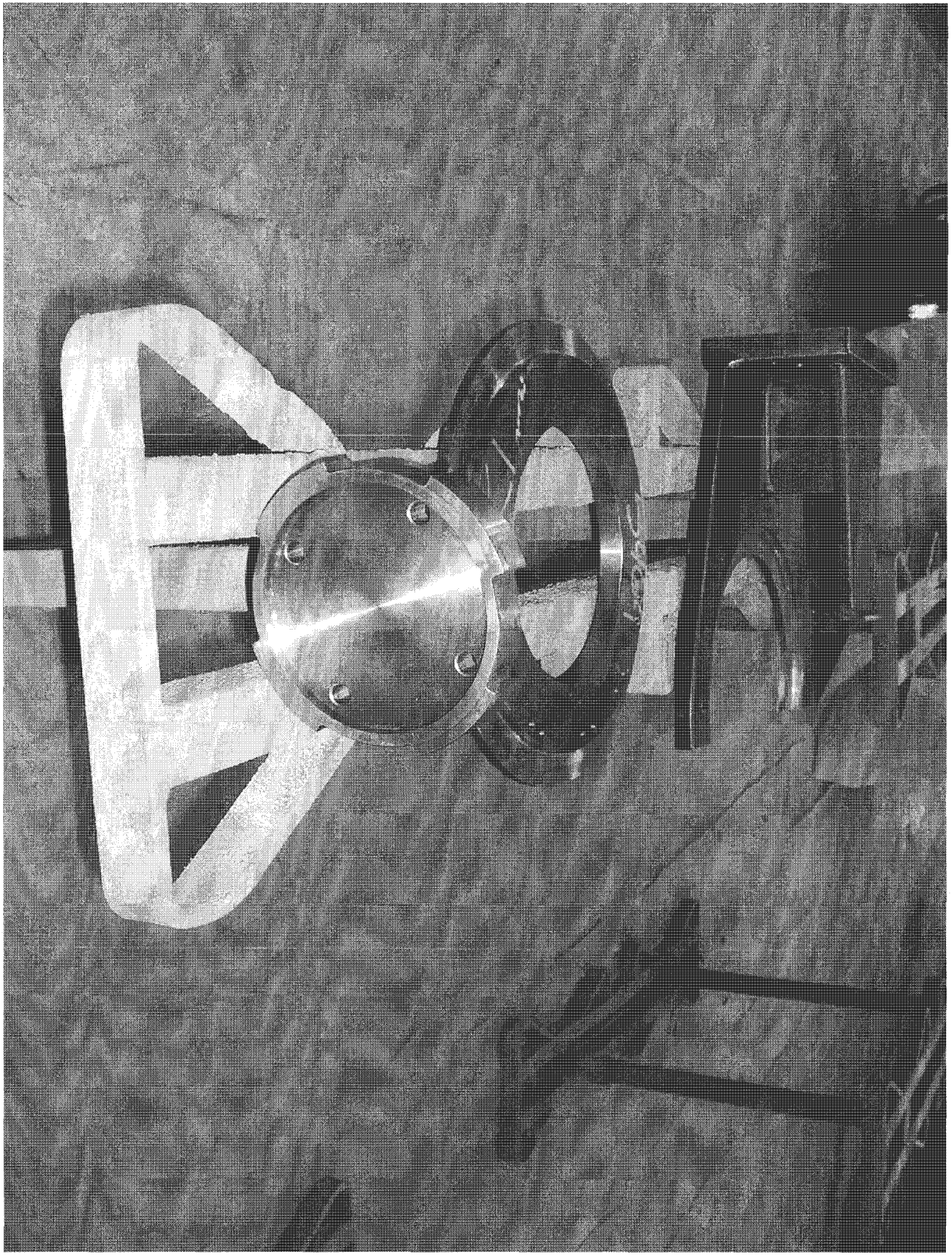

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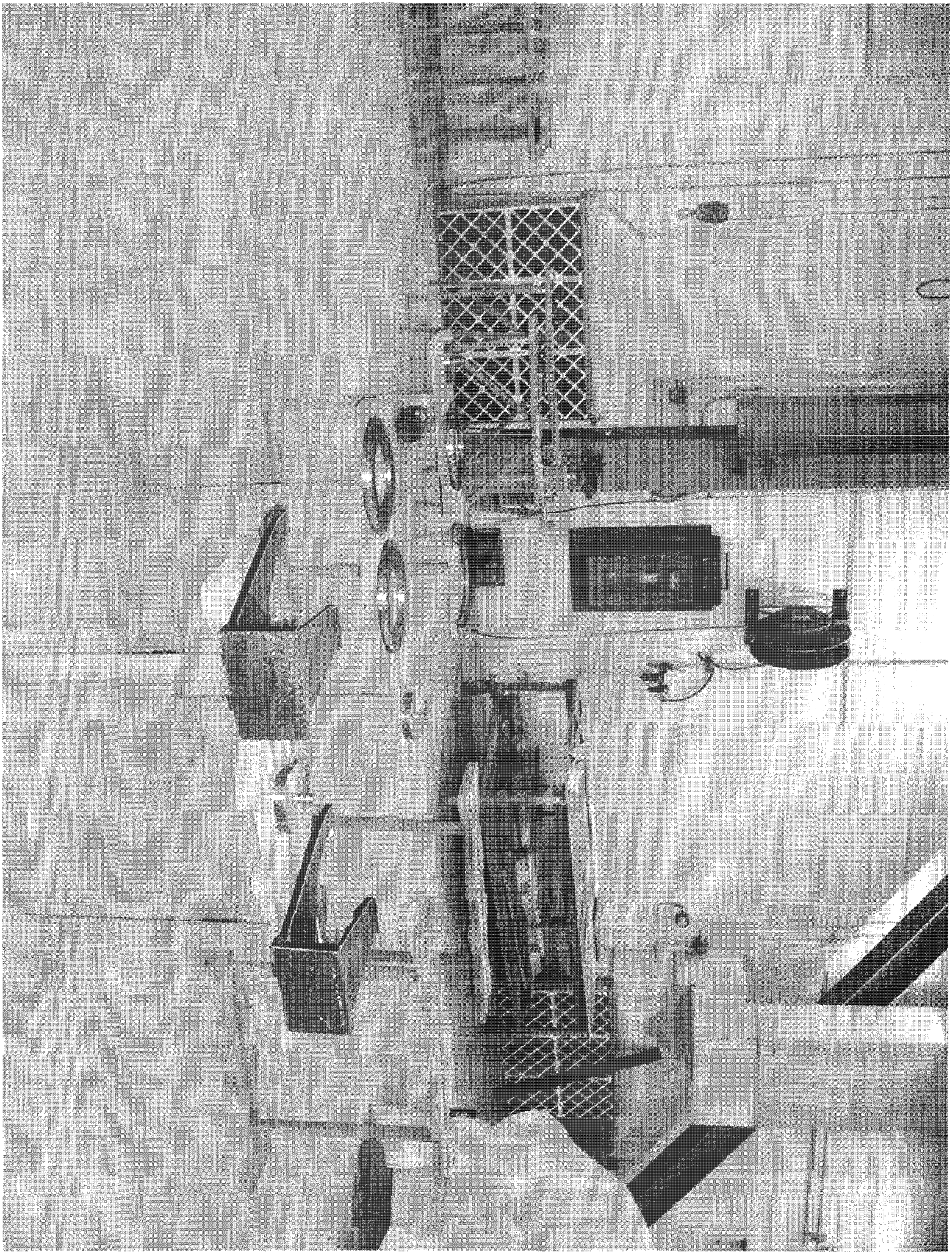

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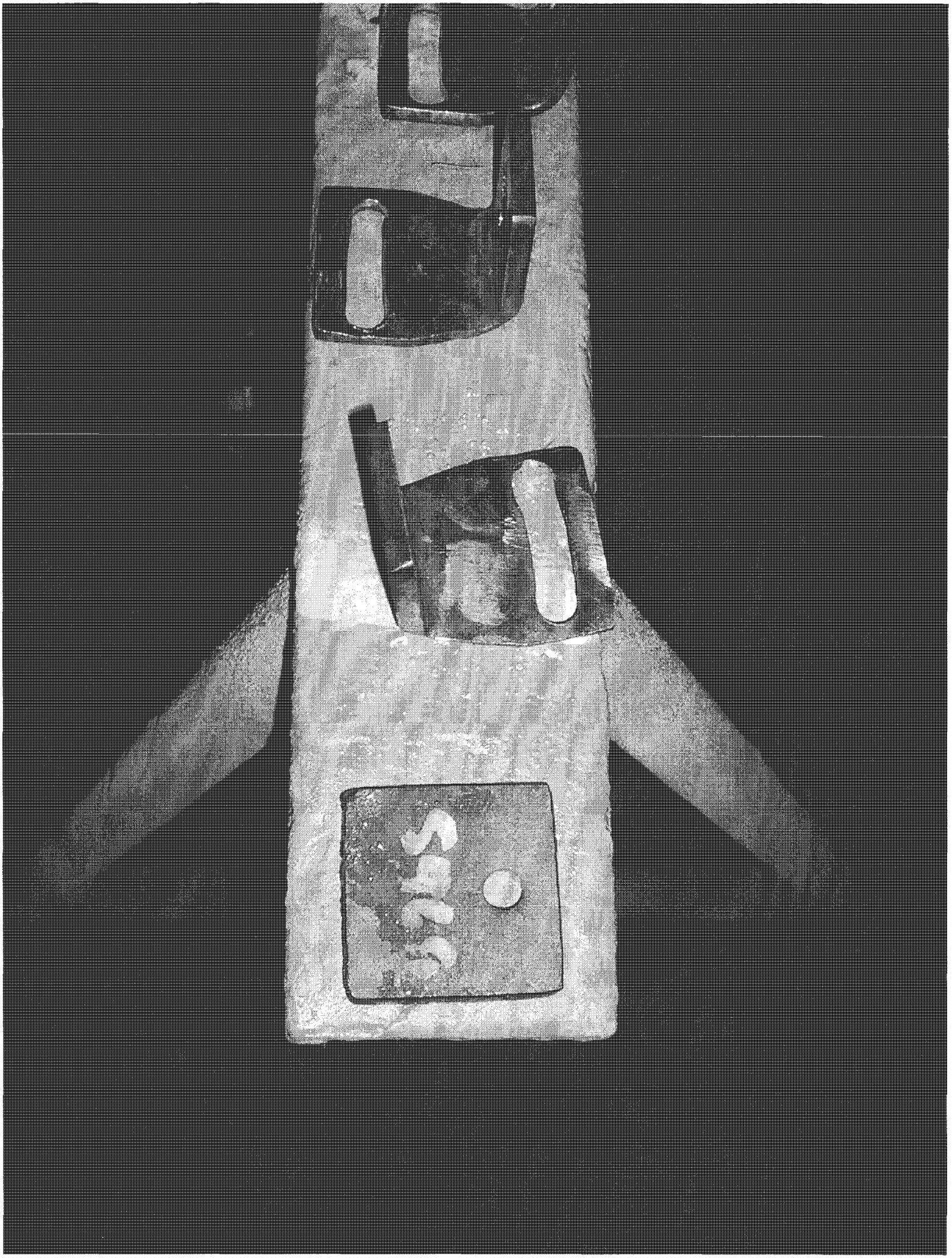

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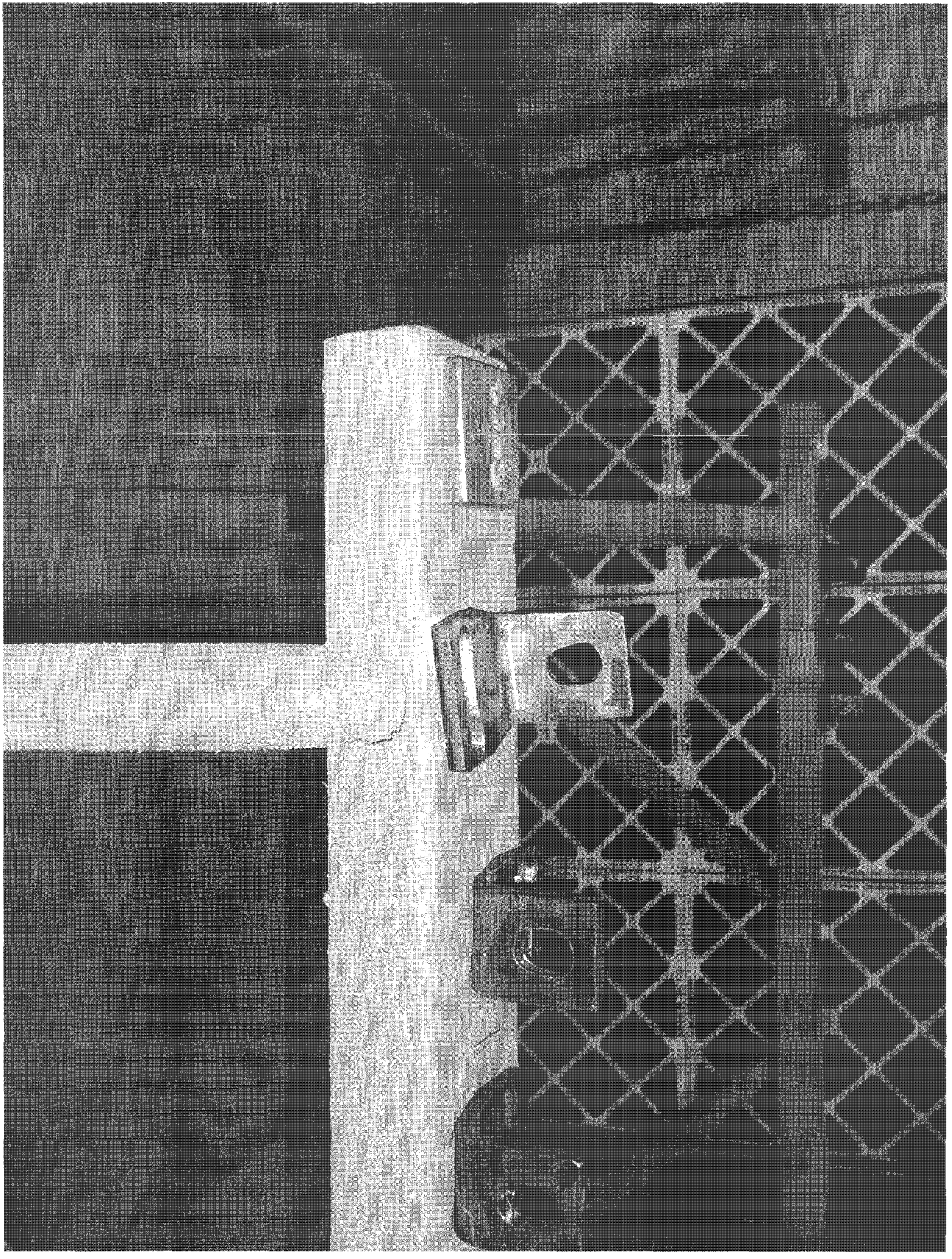

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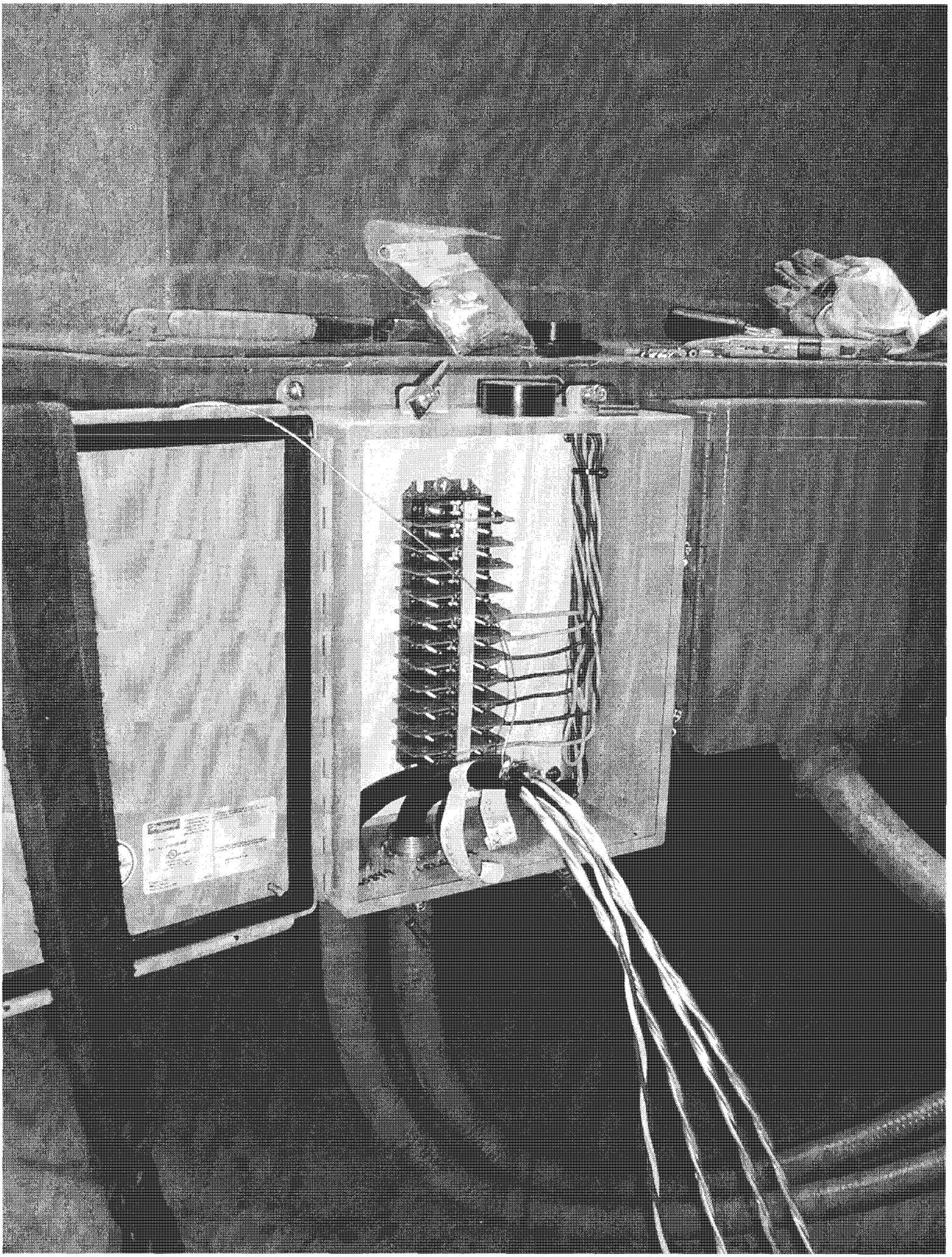

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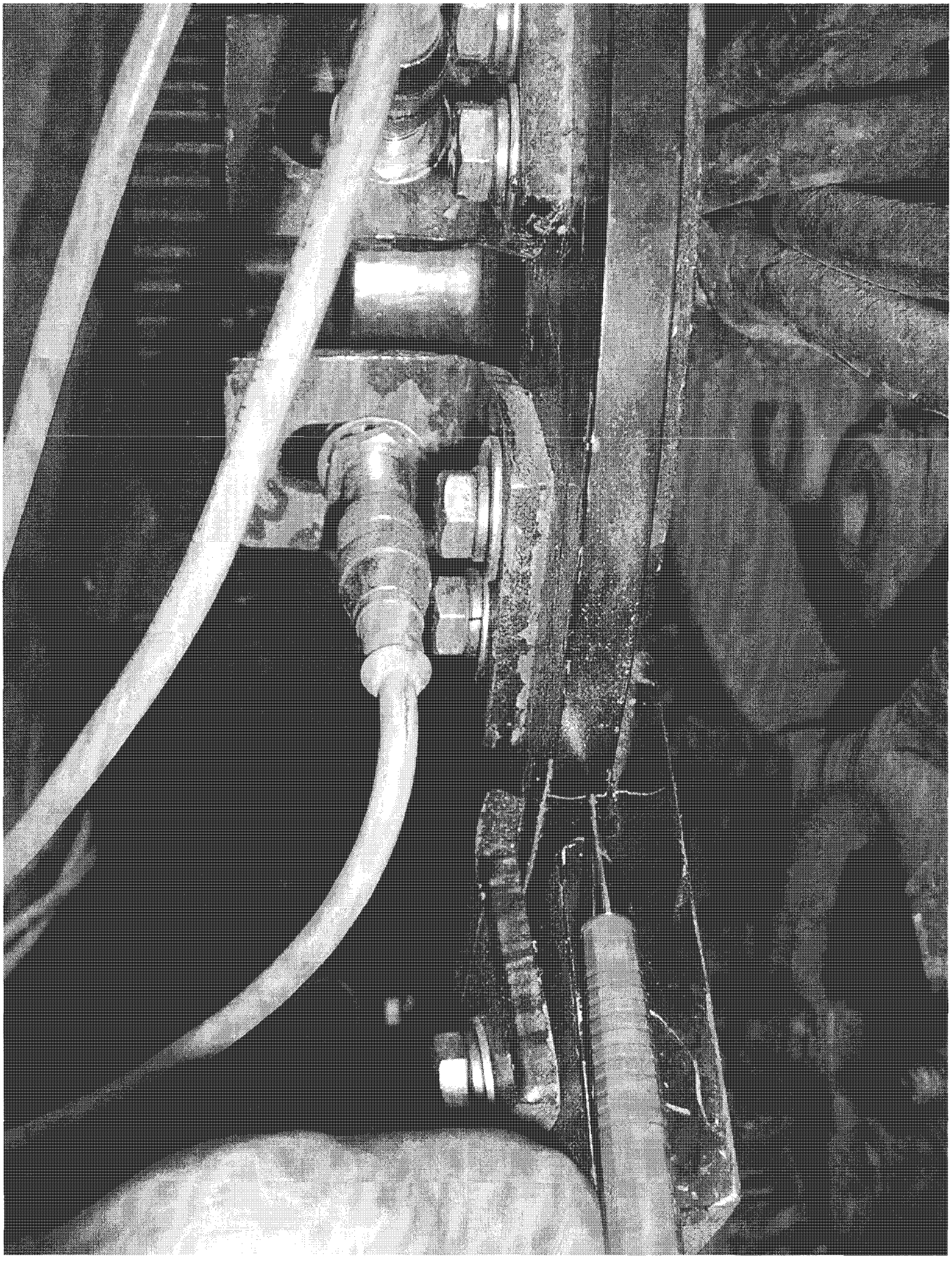

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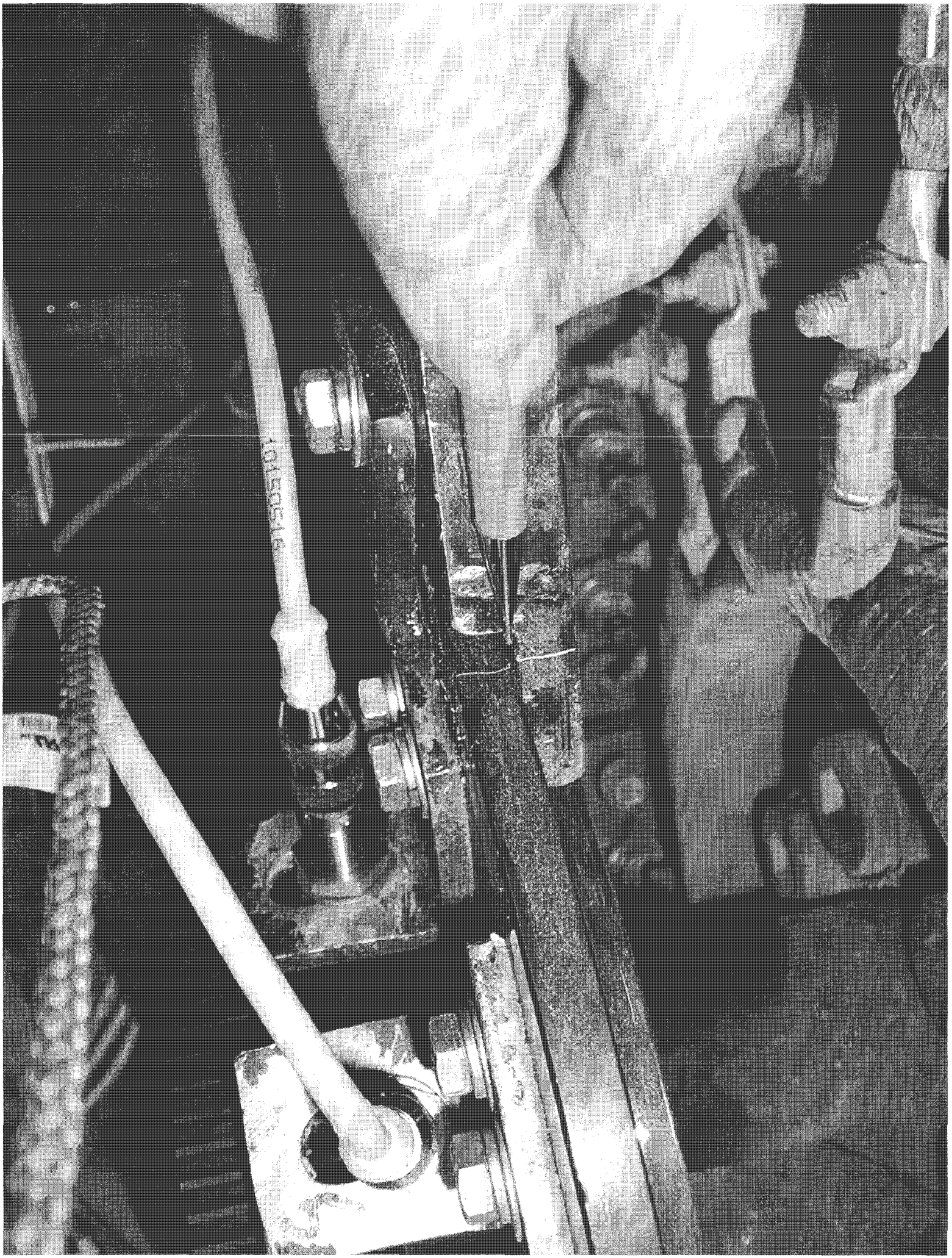

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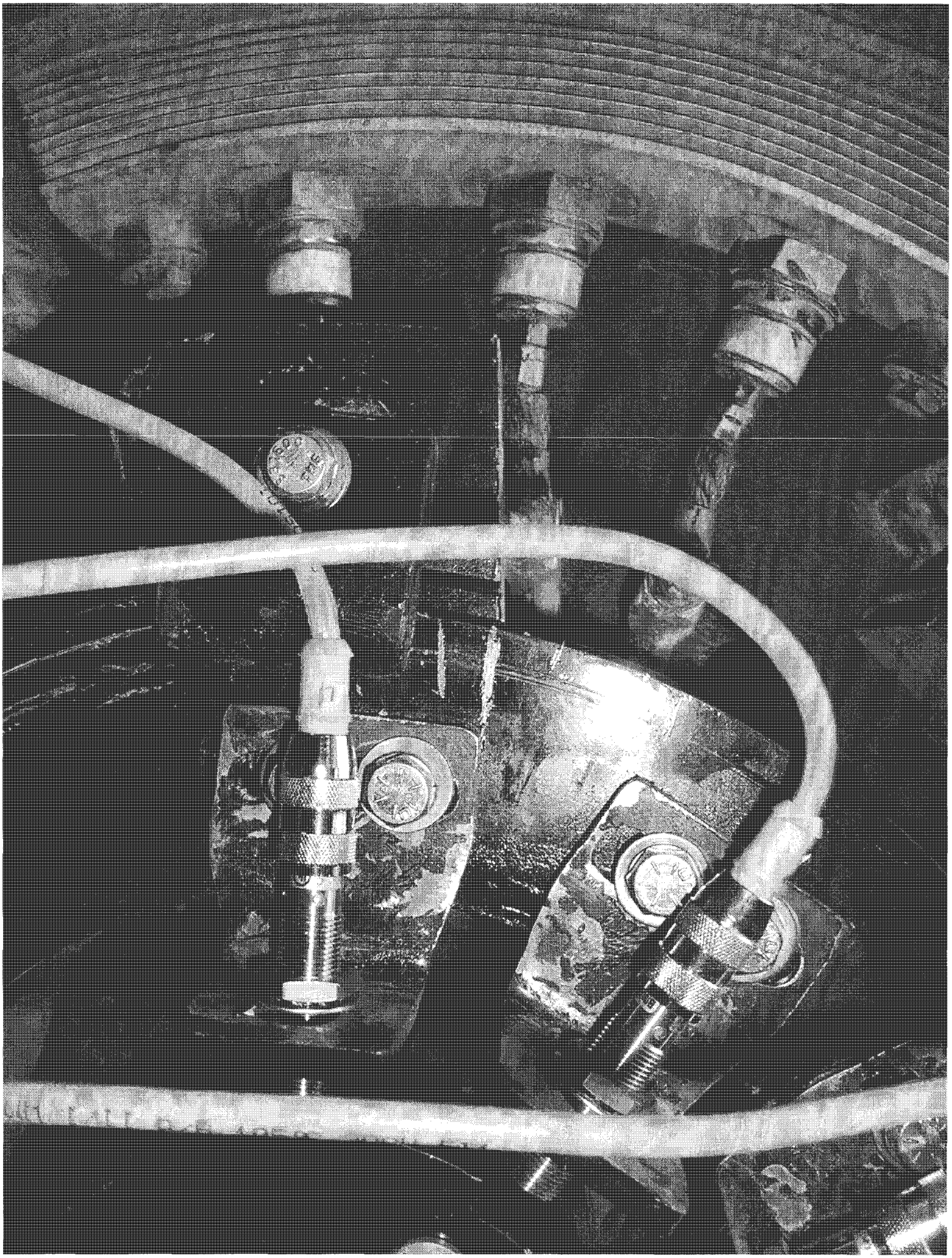

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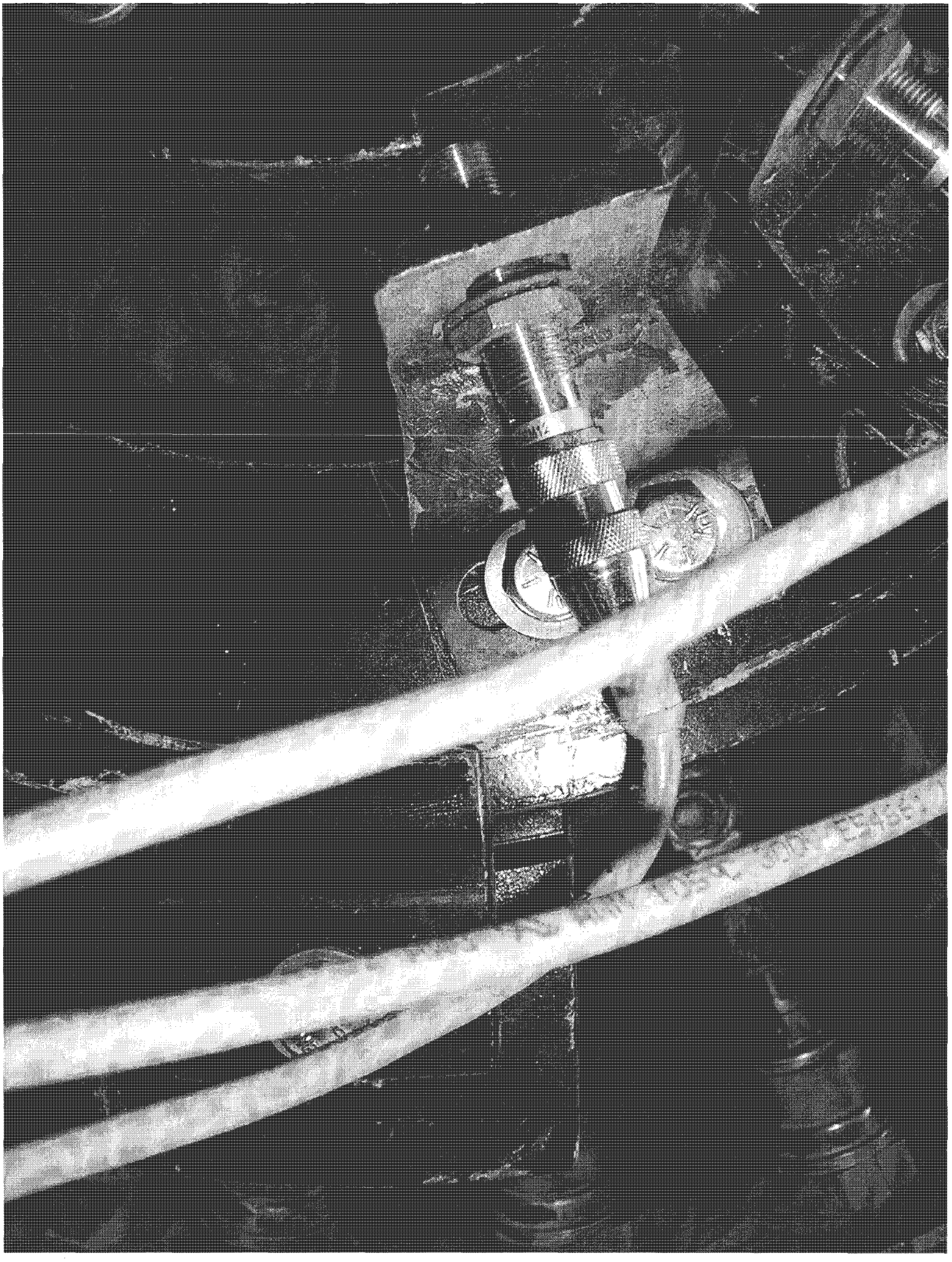

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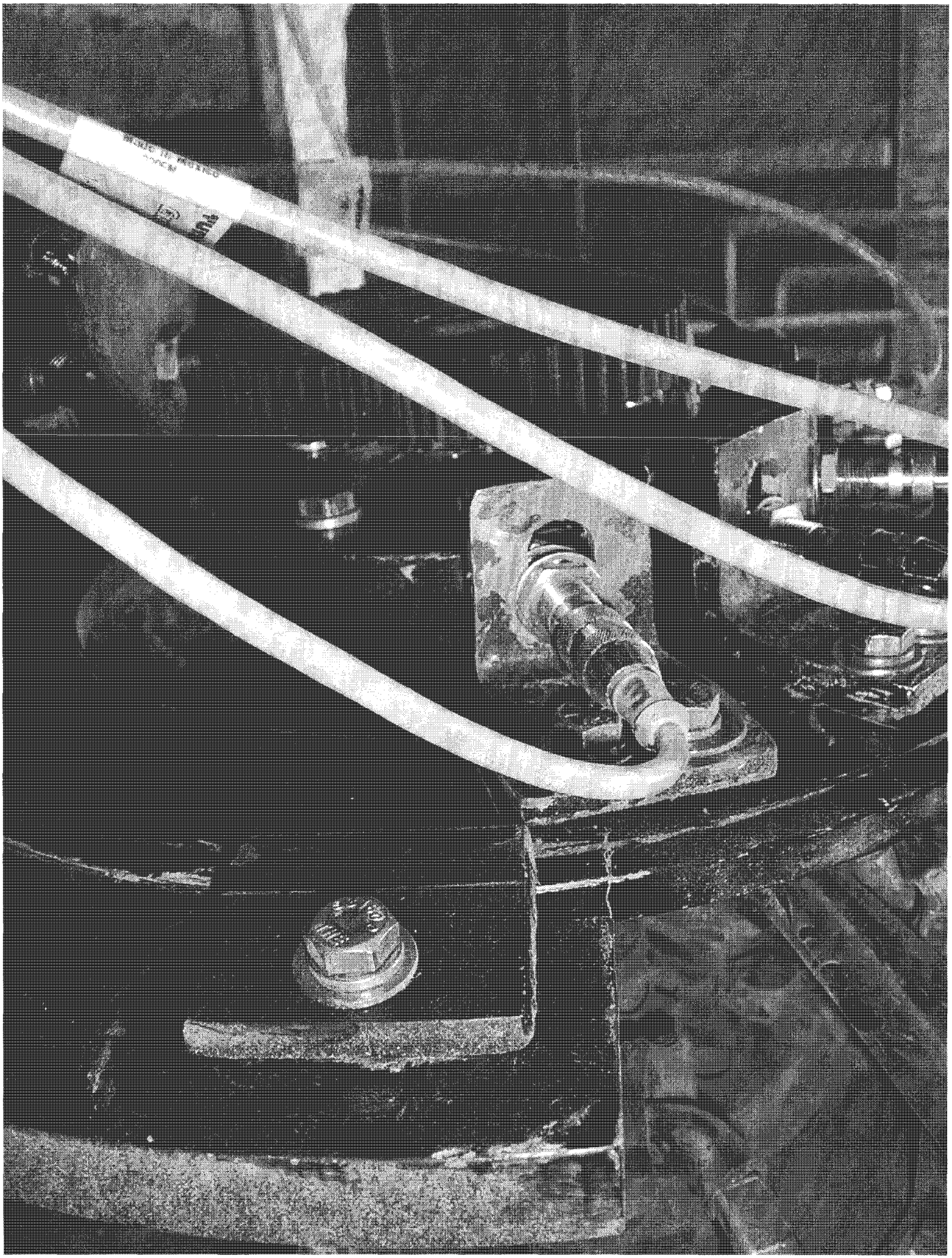

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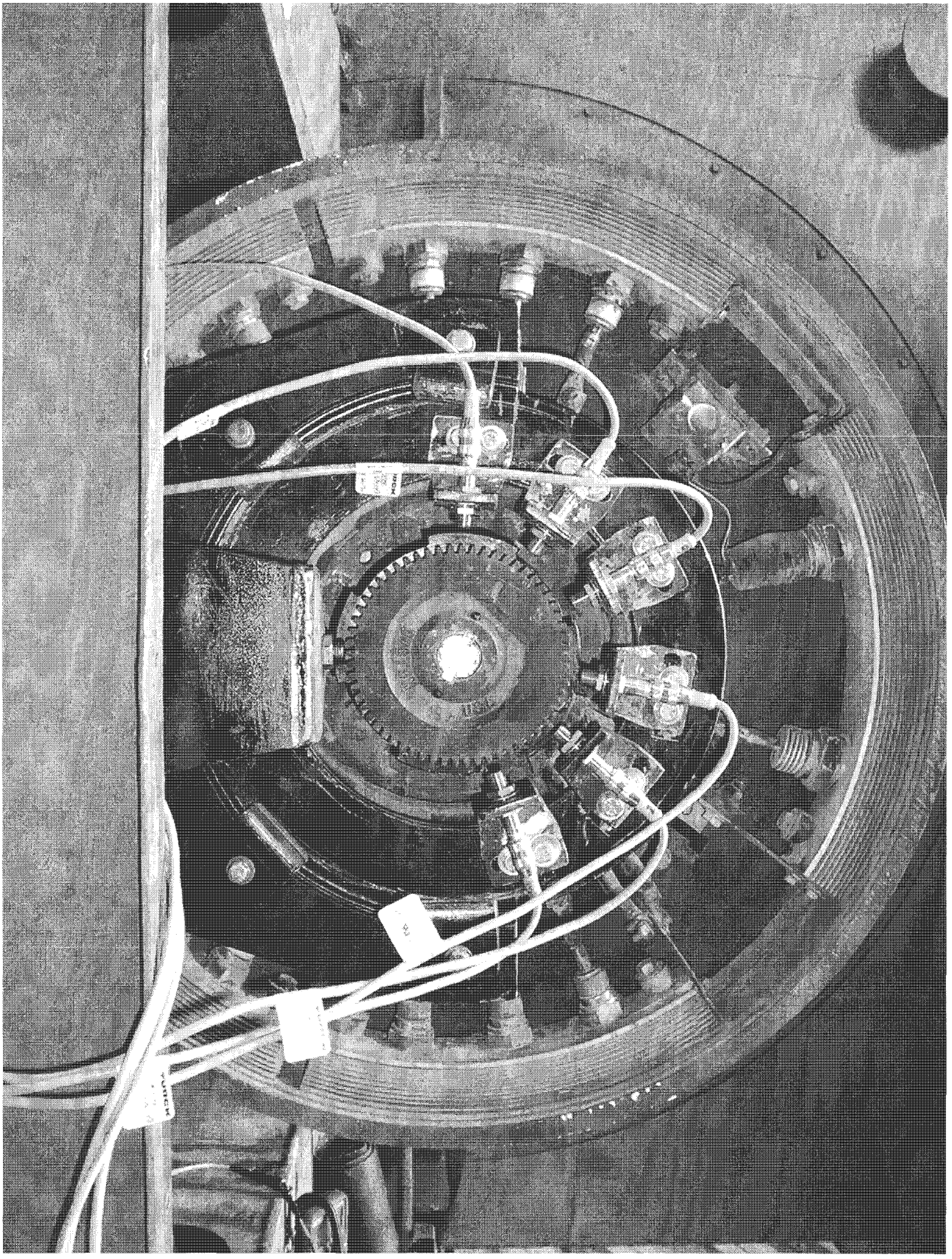

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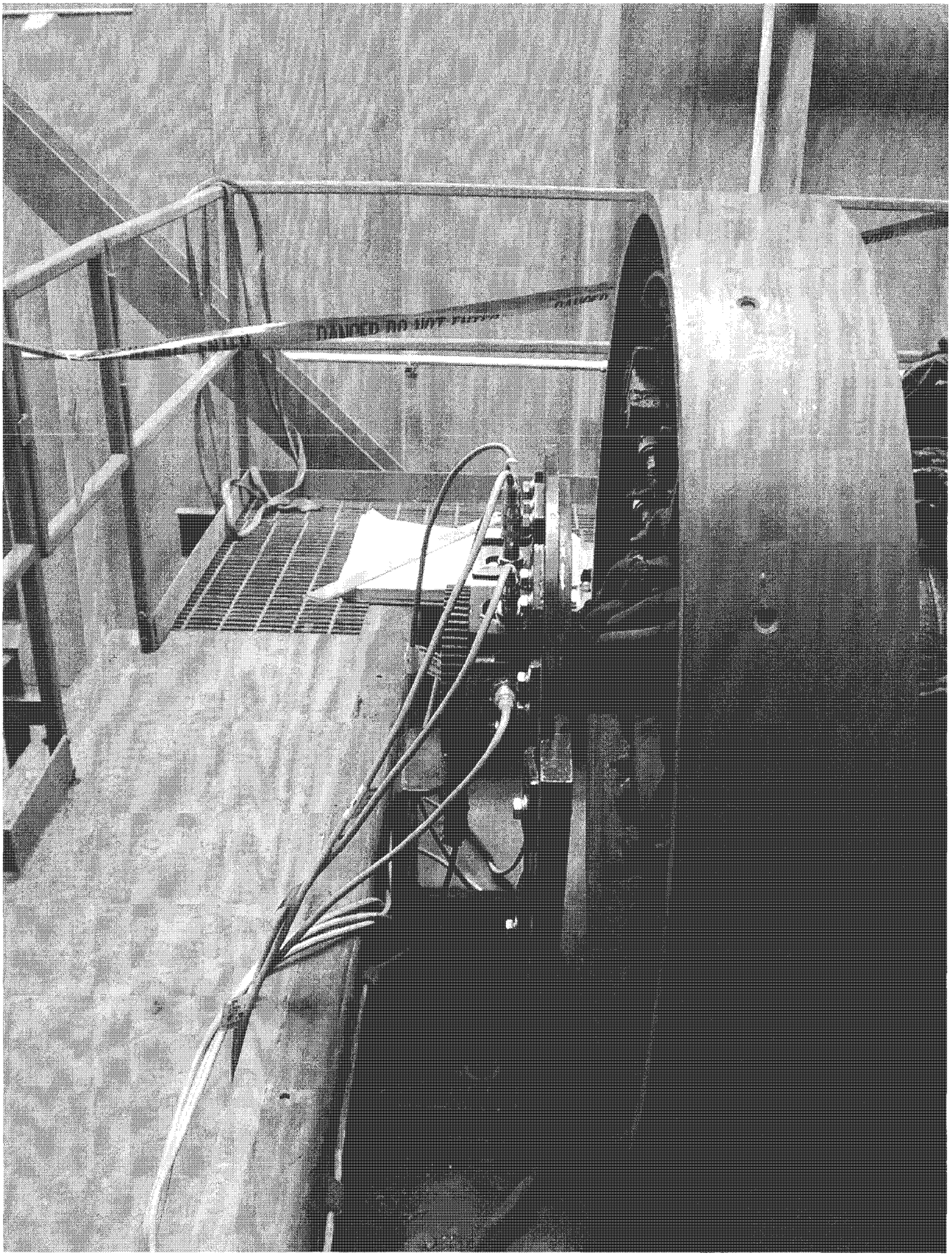

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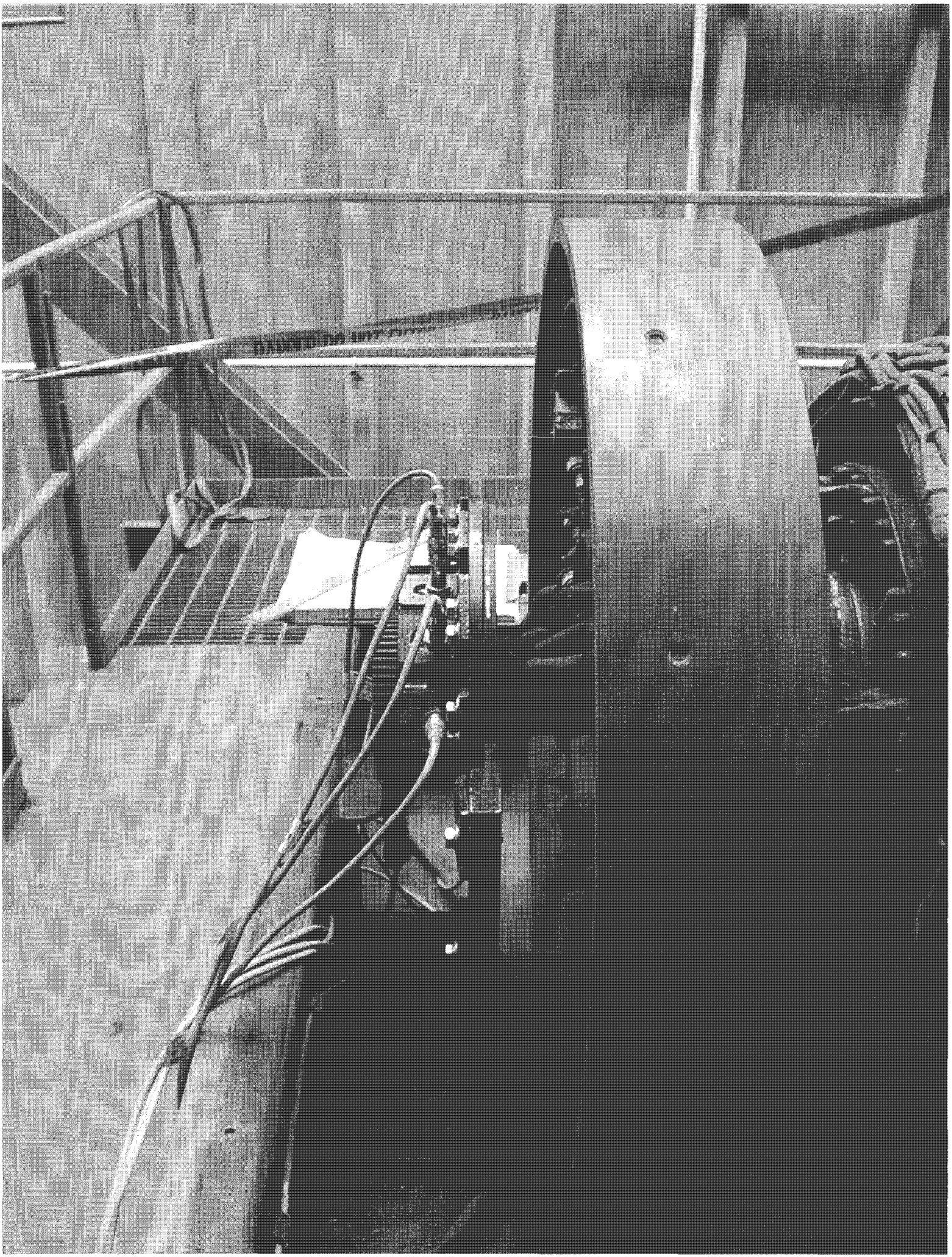

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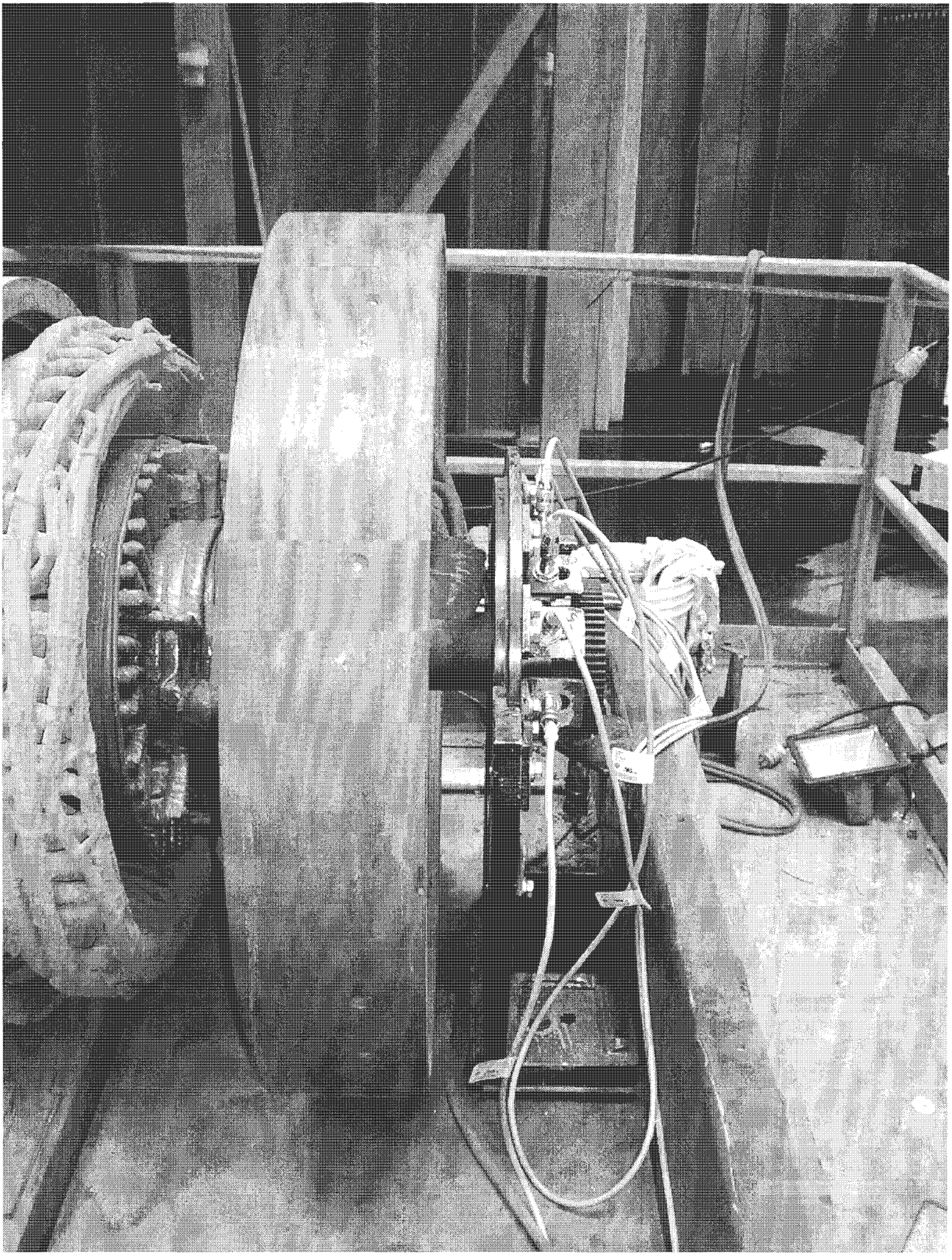

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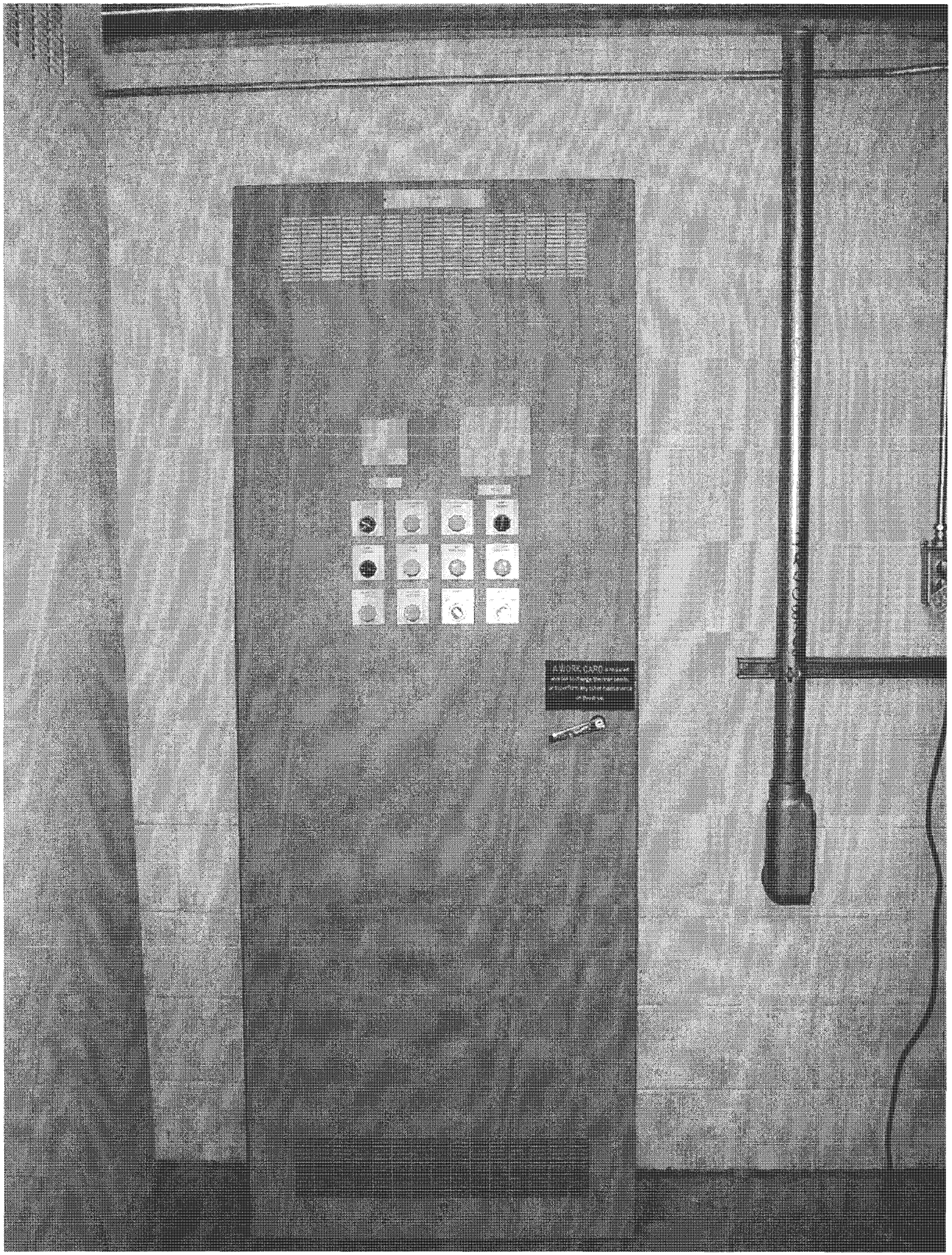

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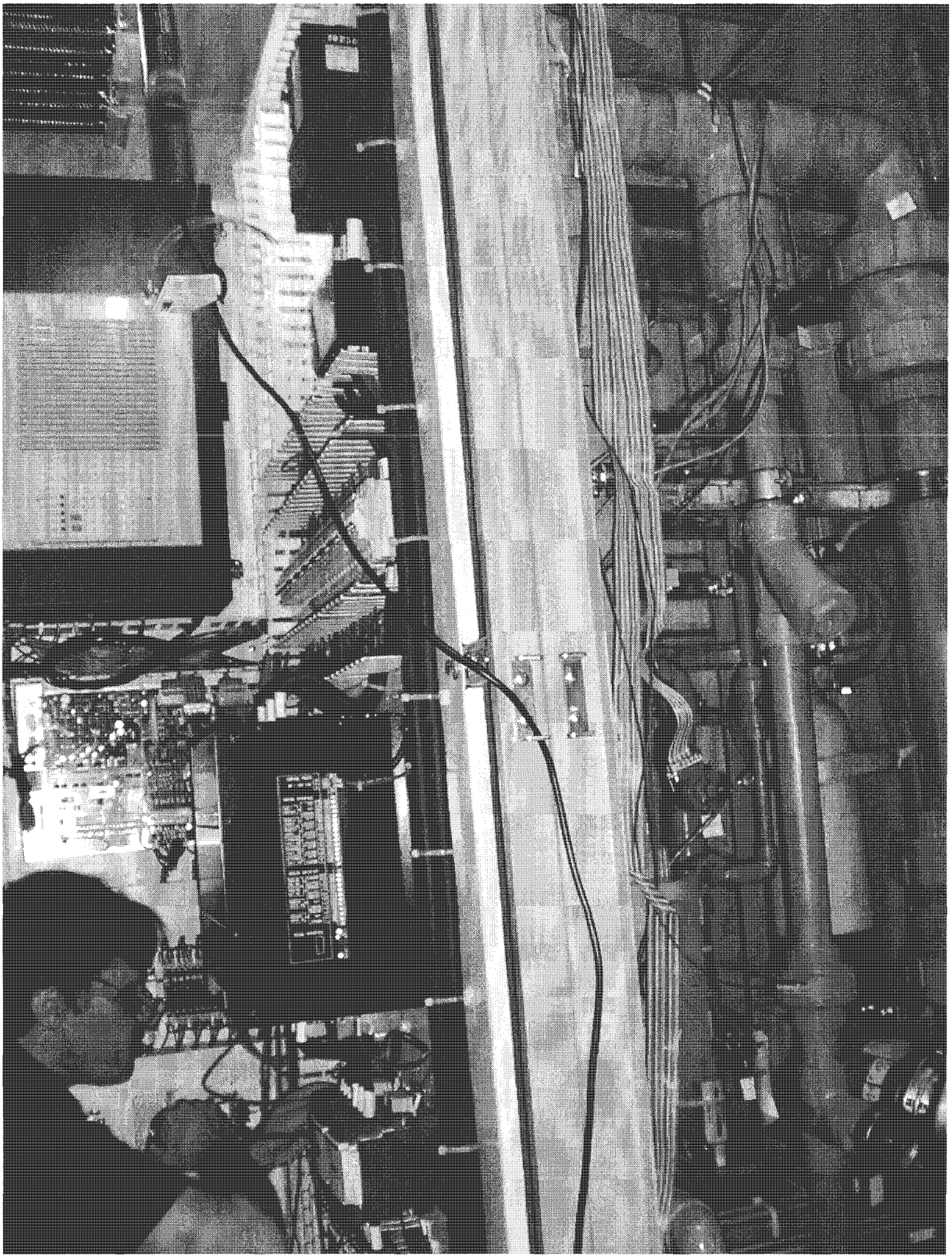

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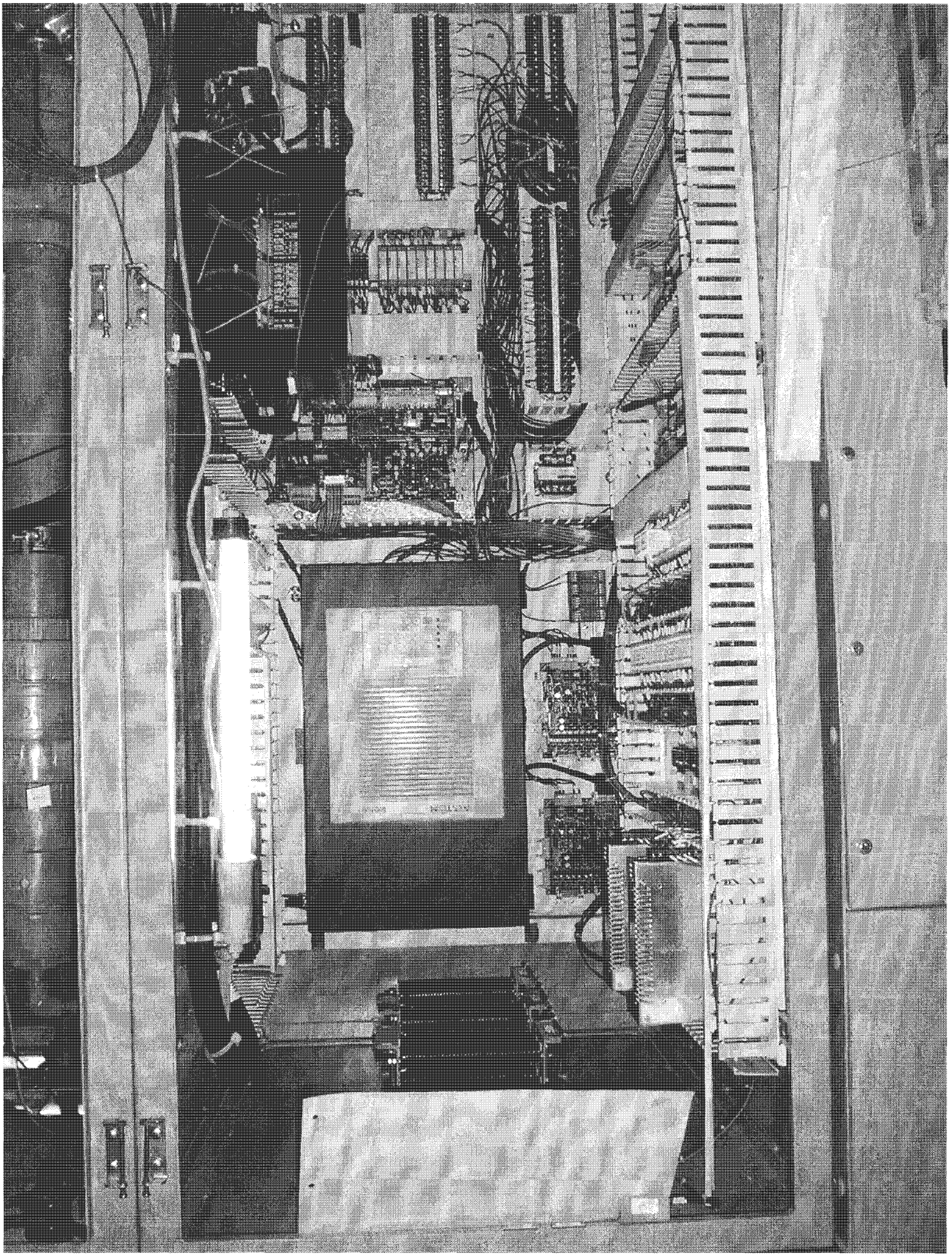

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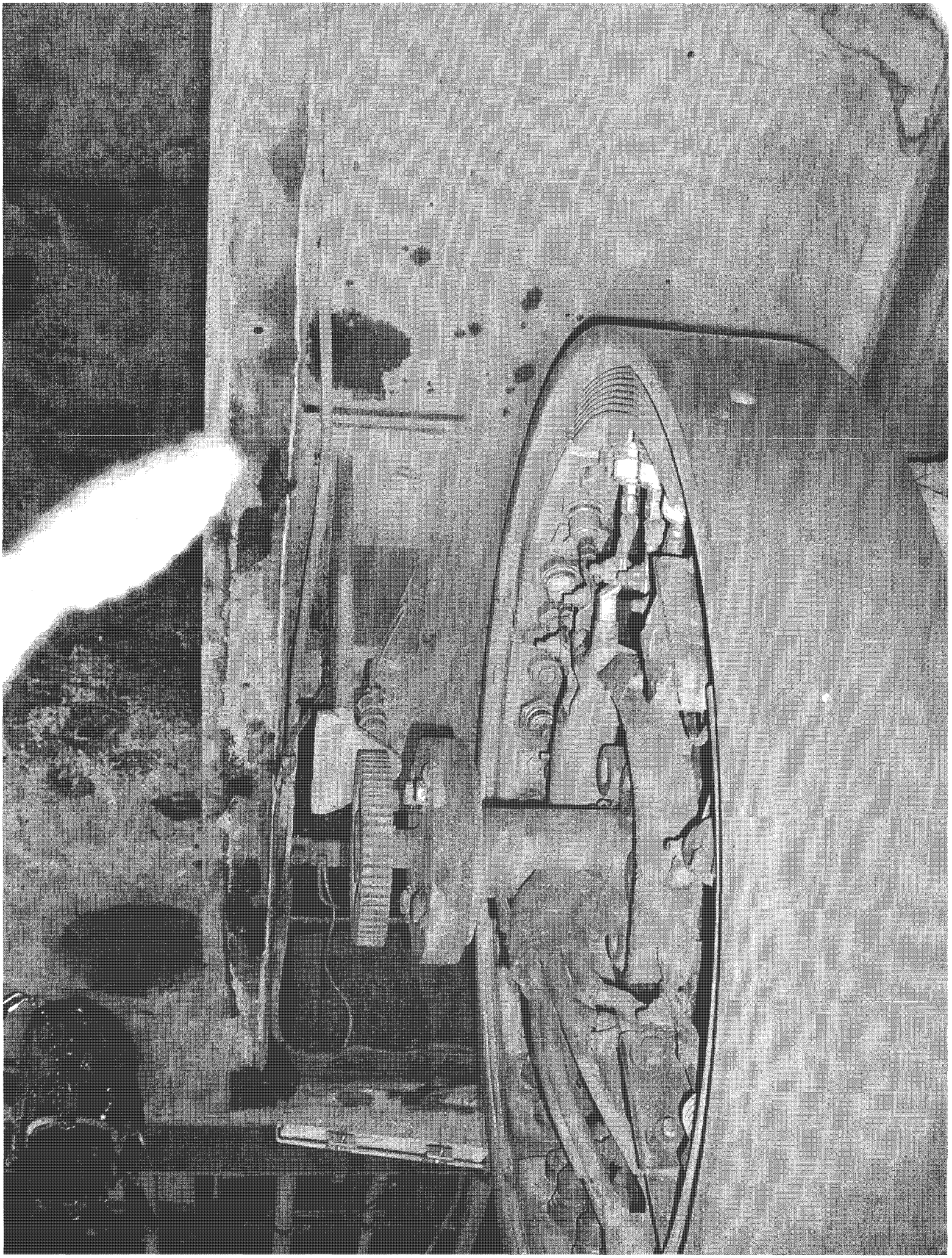

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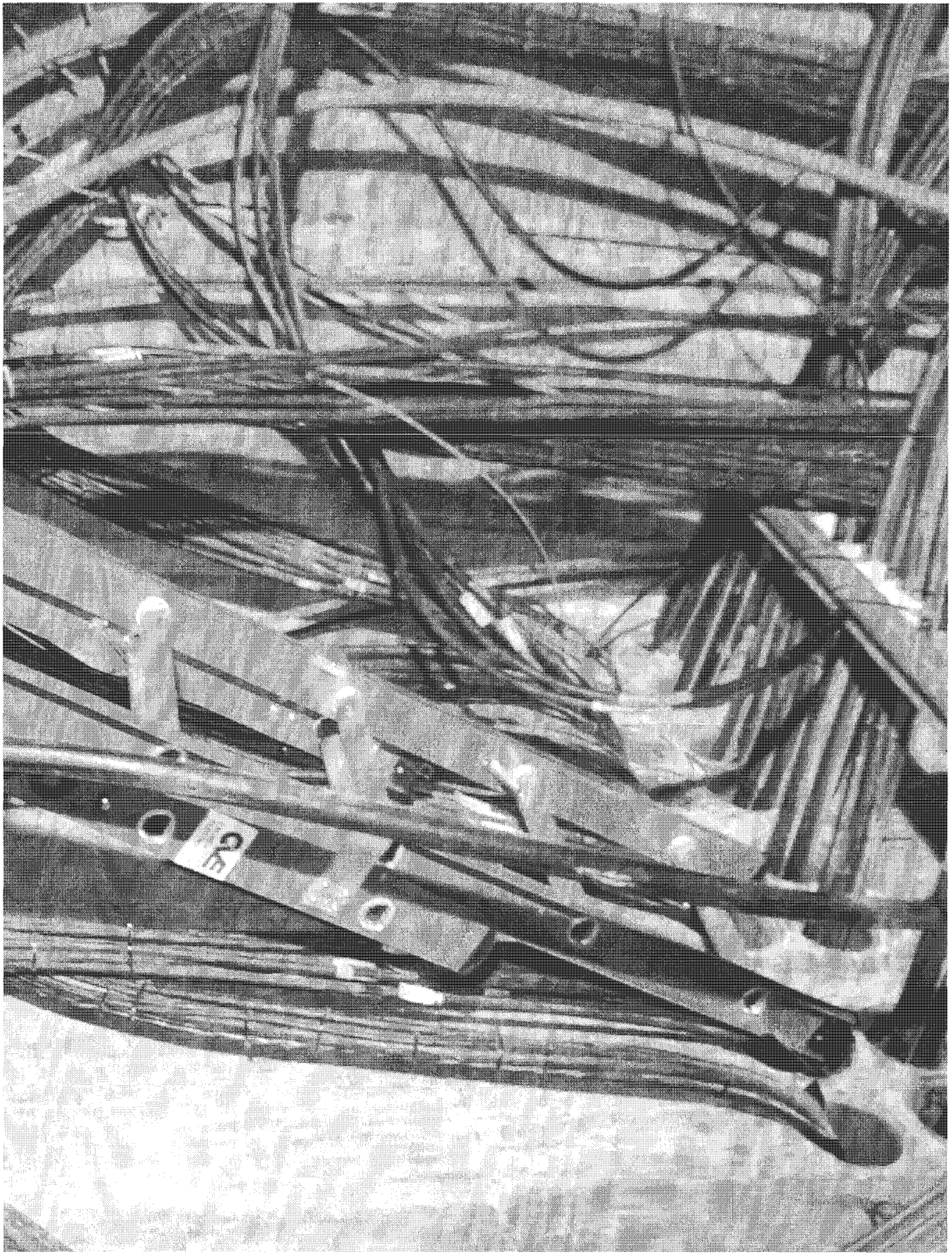
IP7015220



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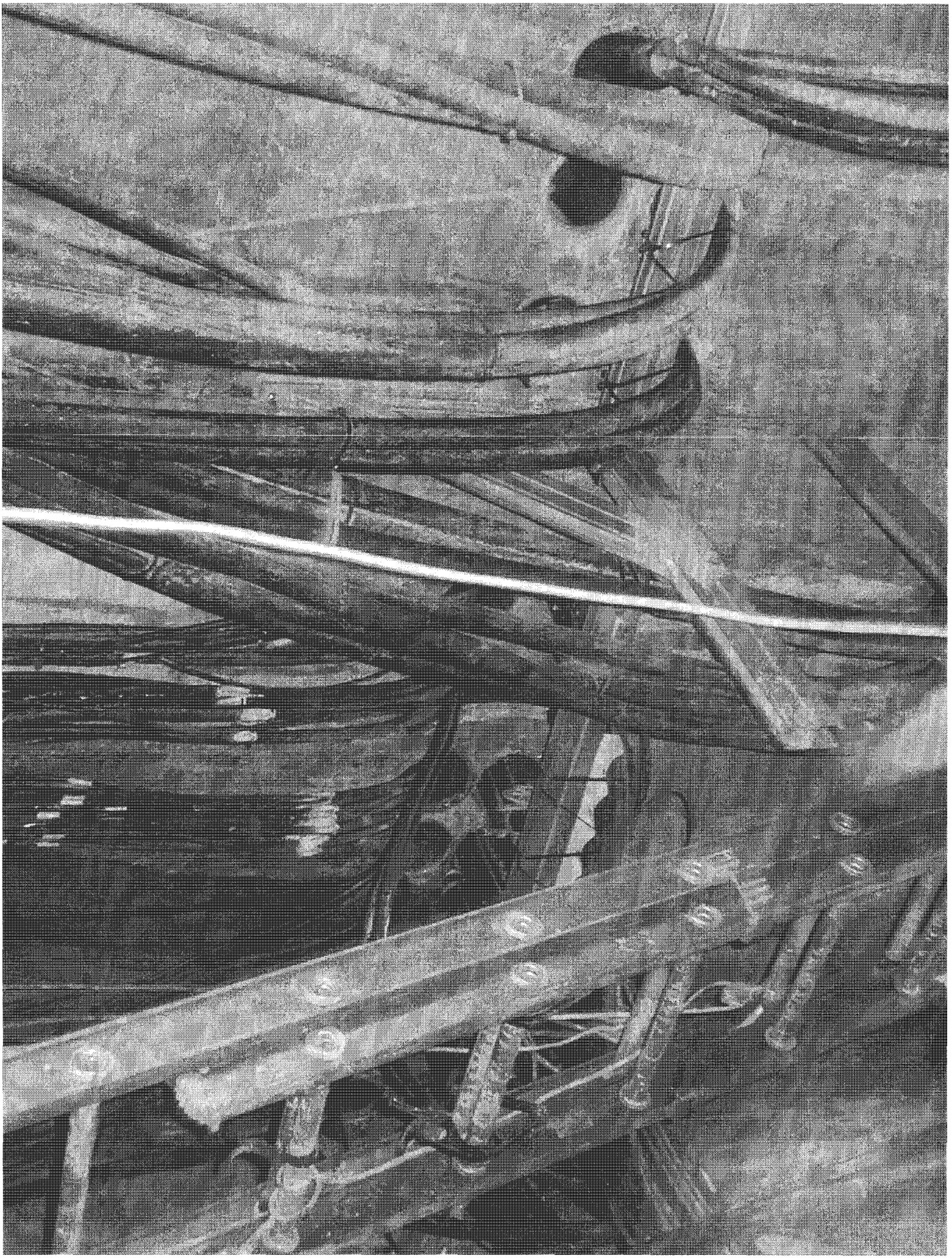

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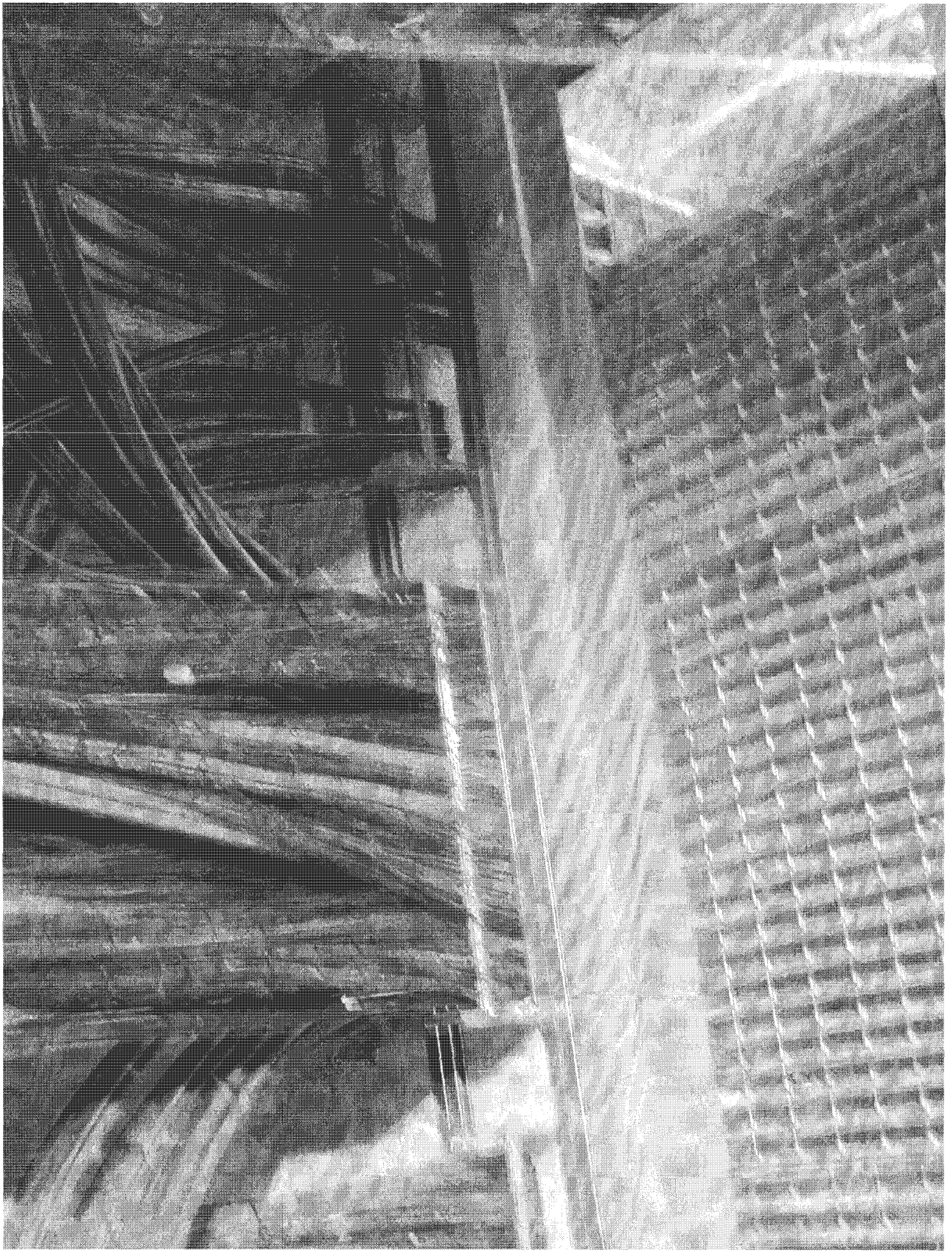

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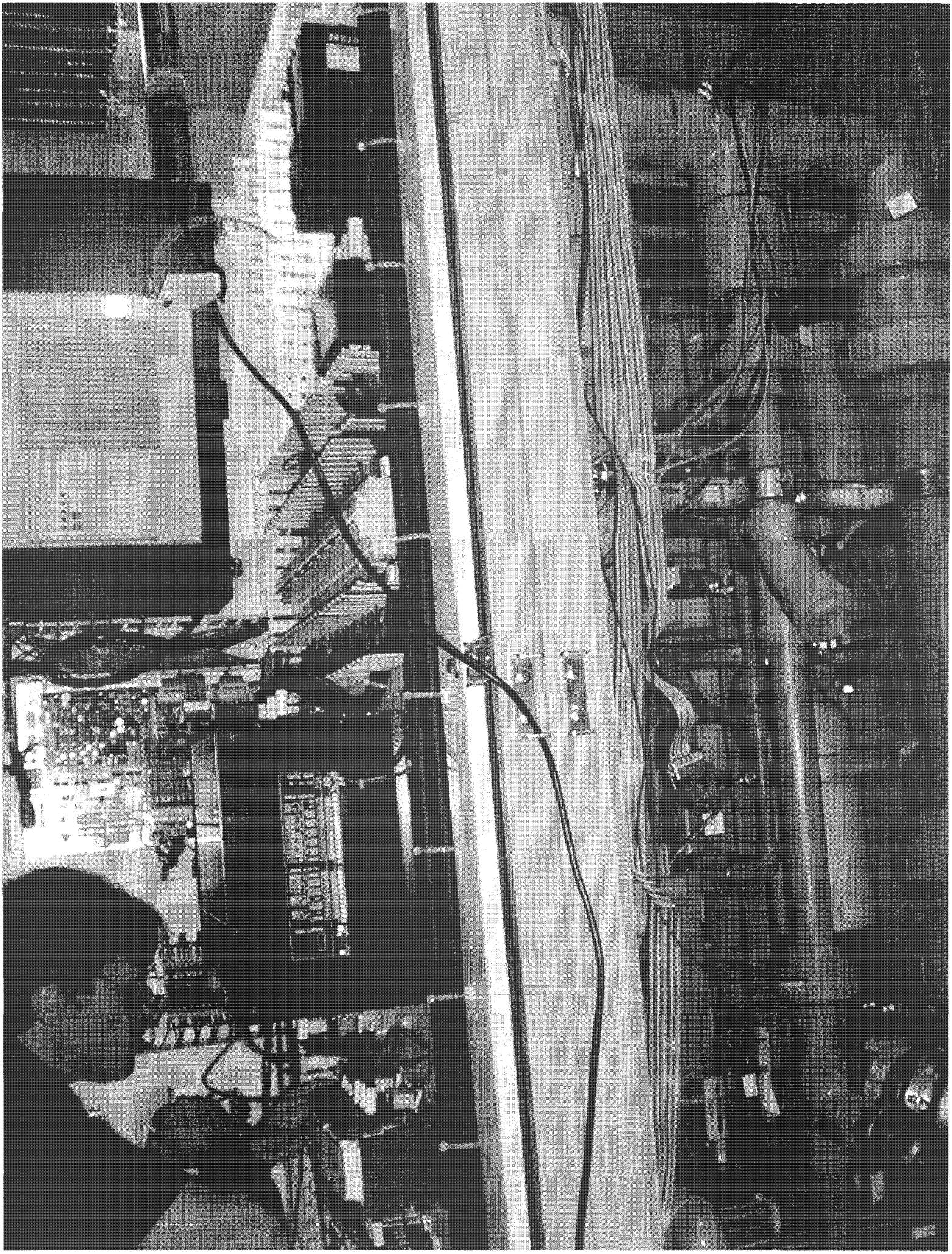

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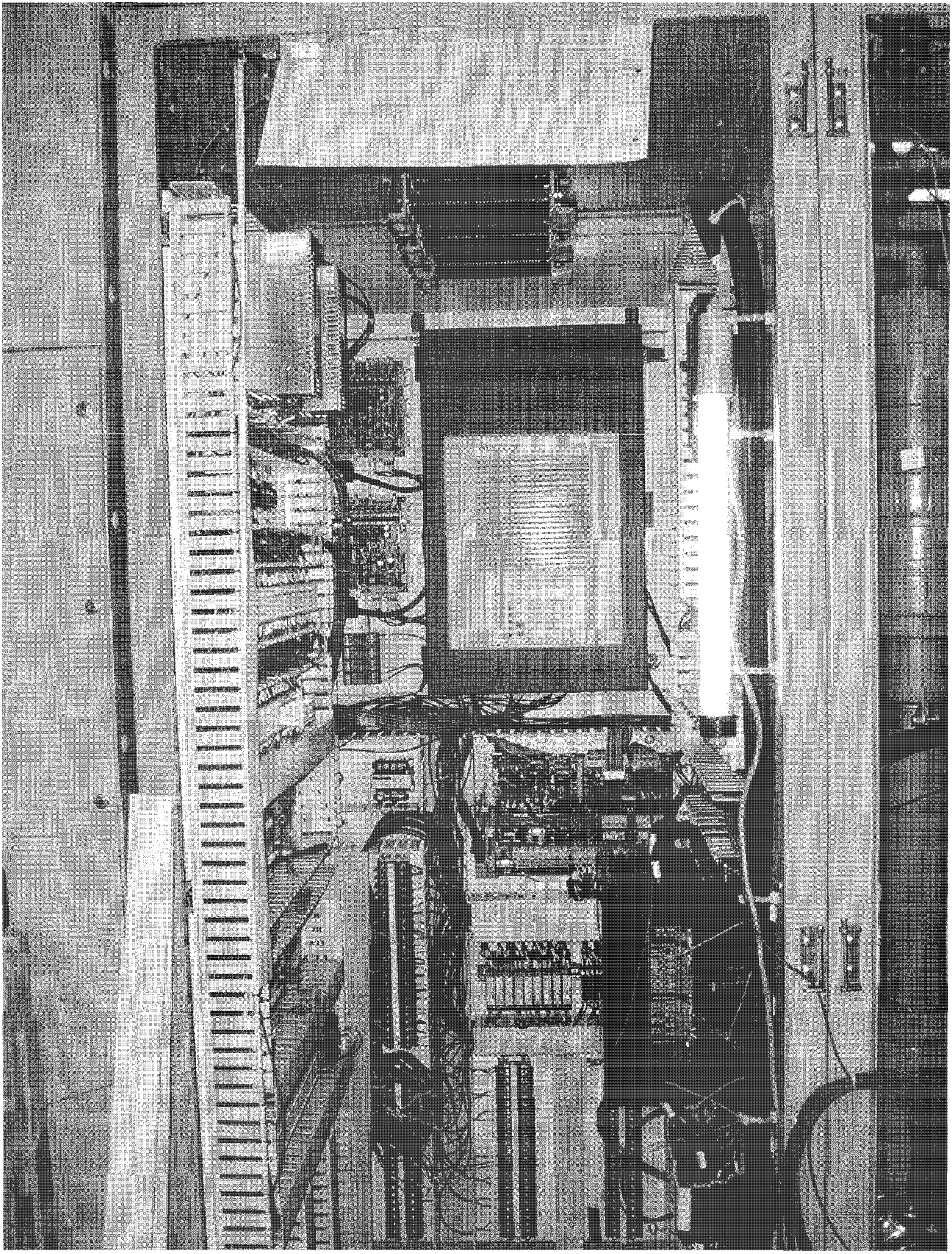

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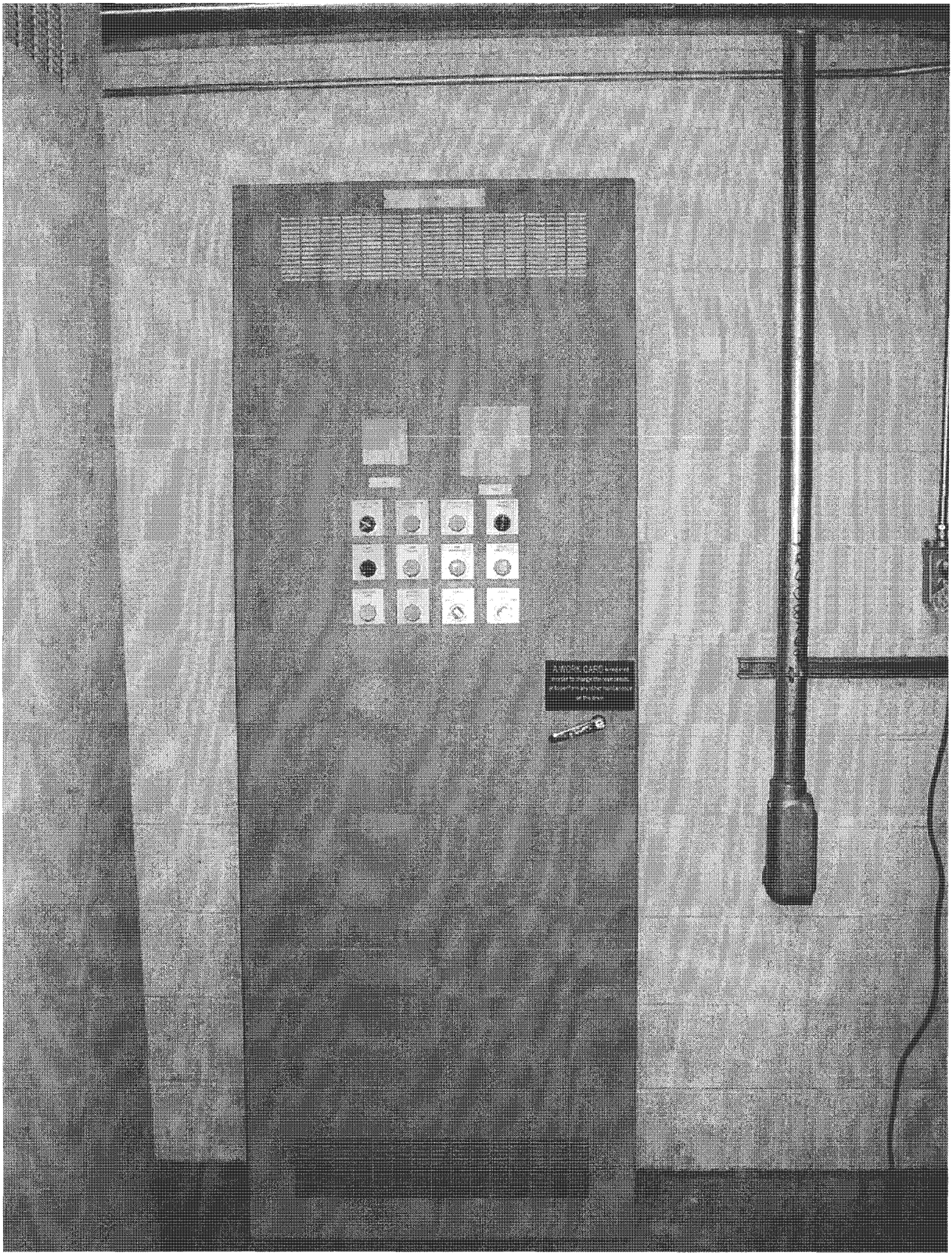

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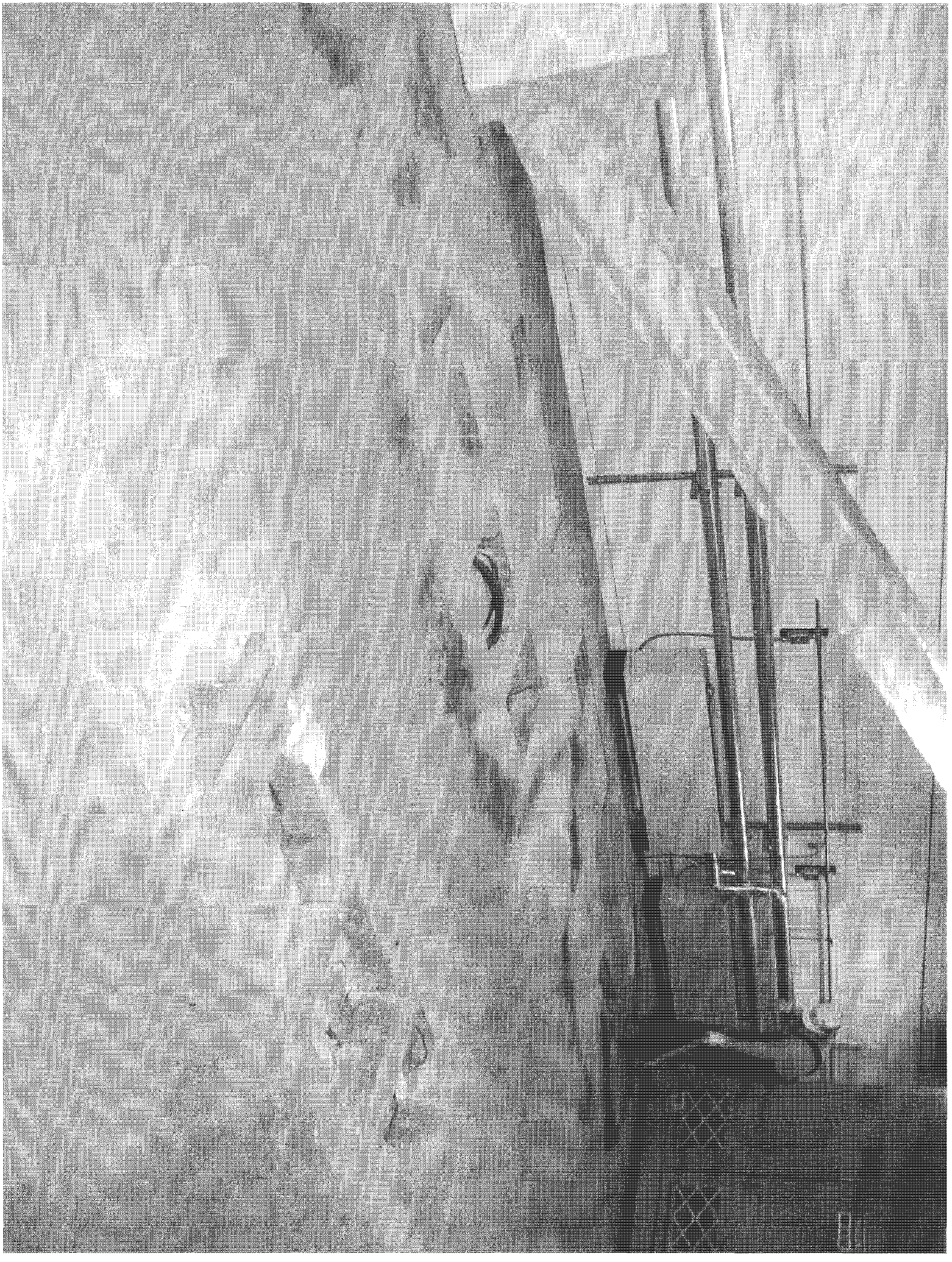

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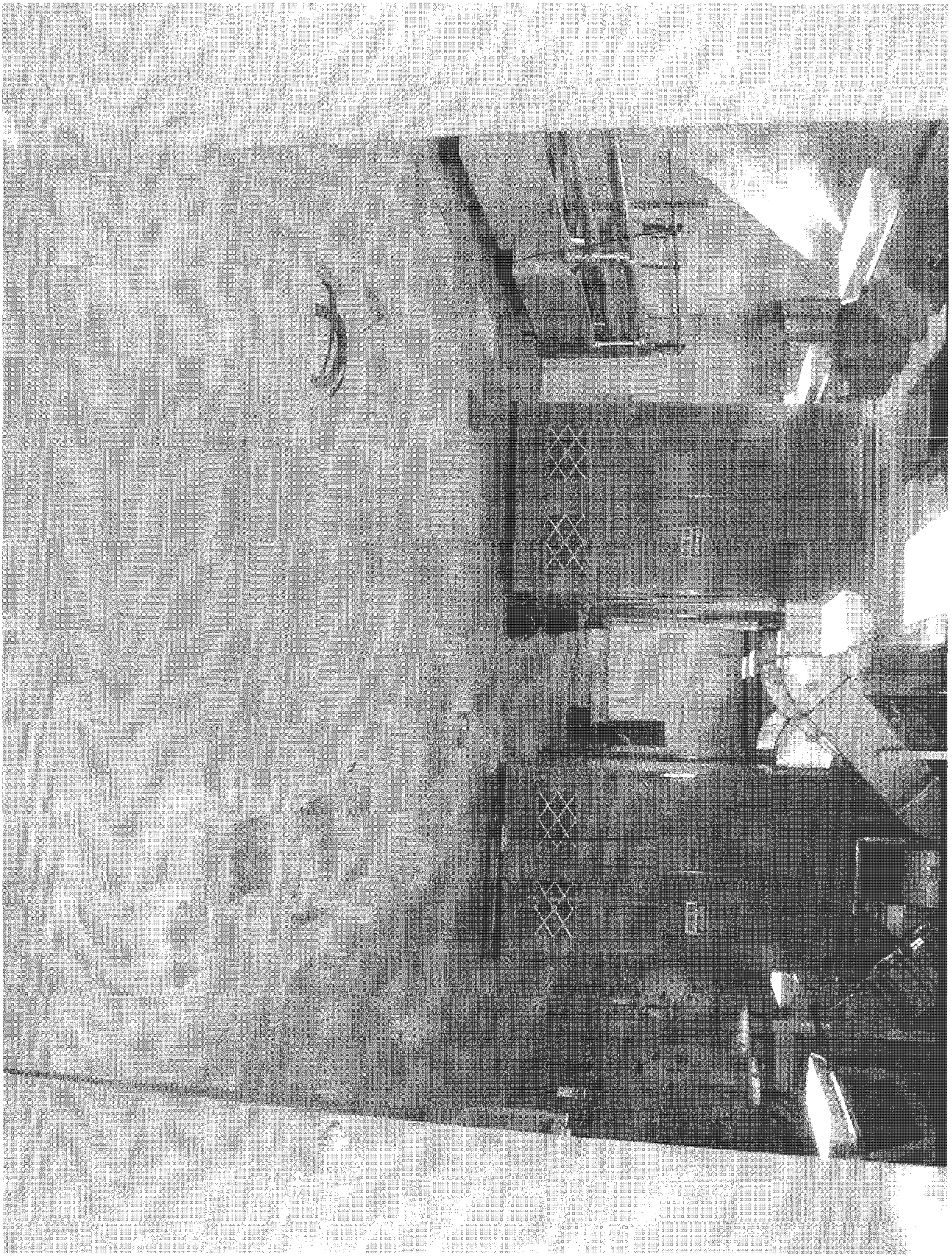

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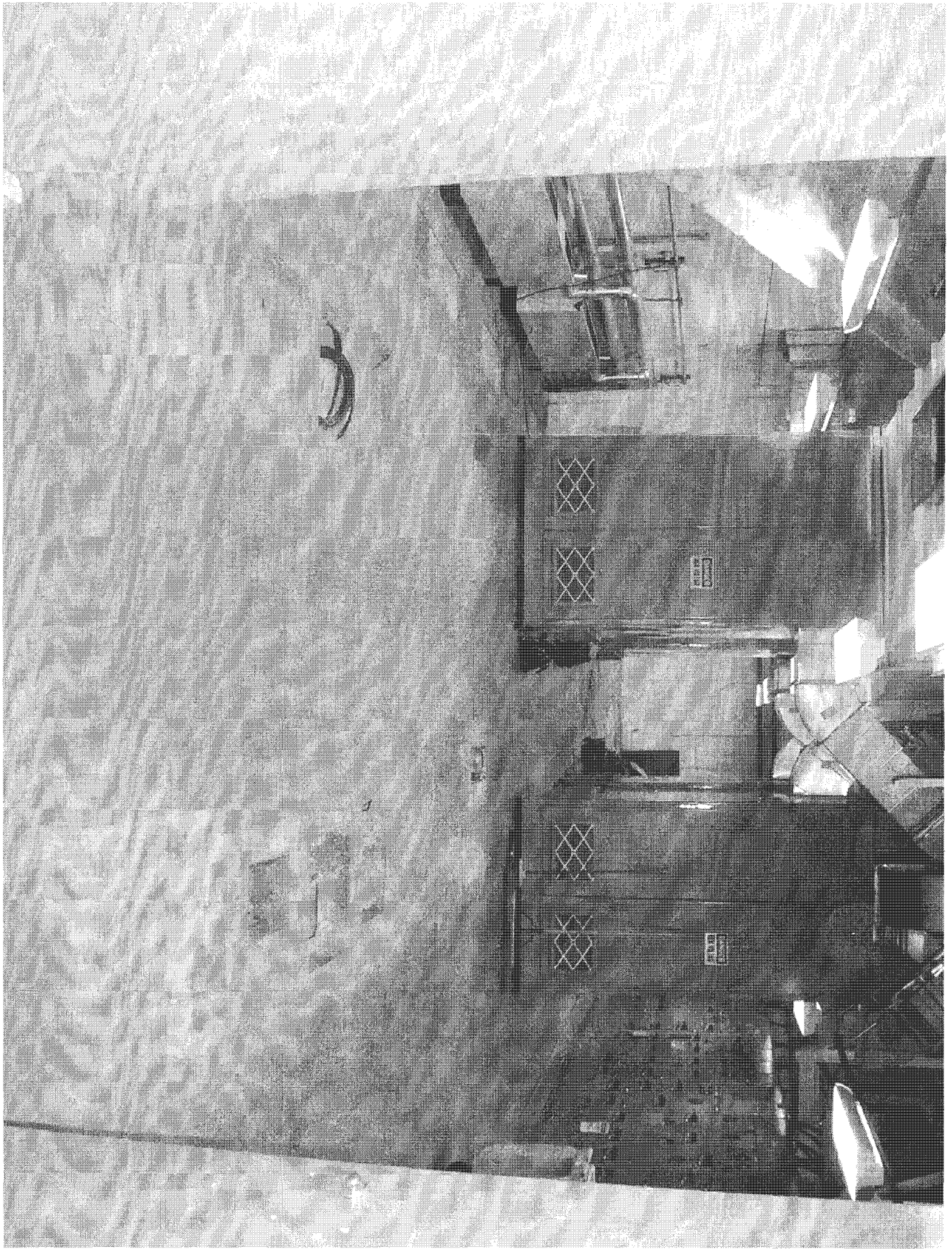

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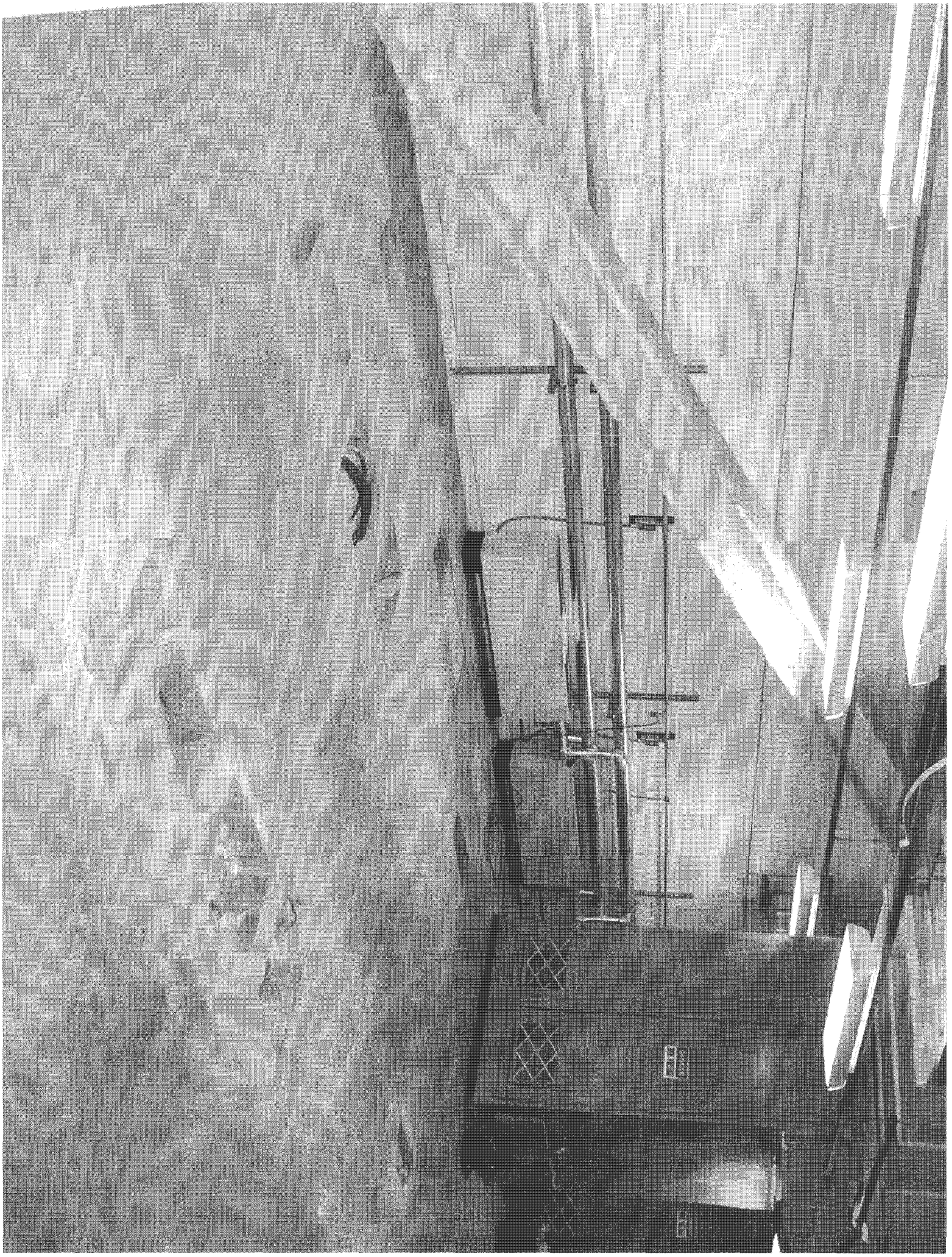

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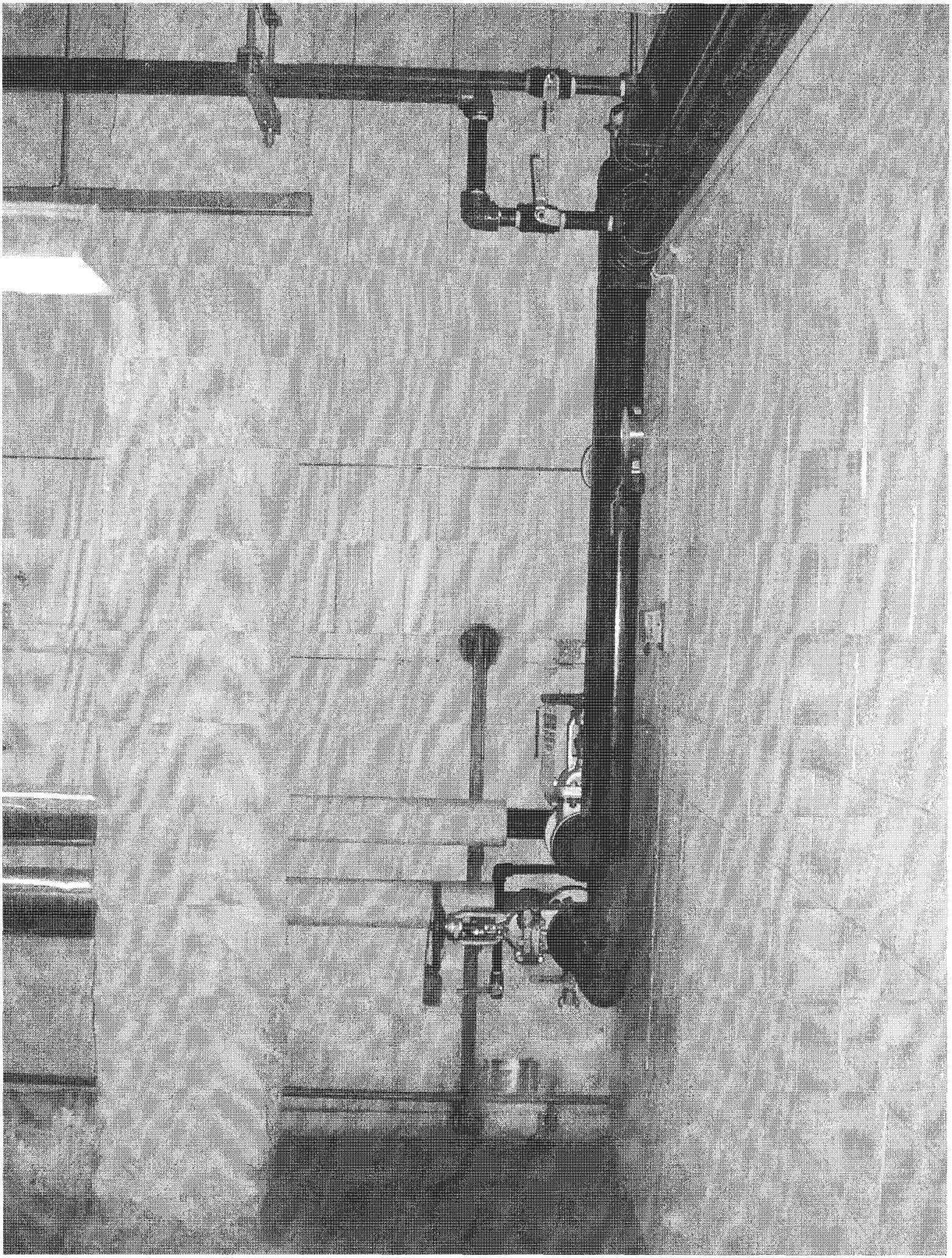

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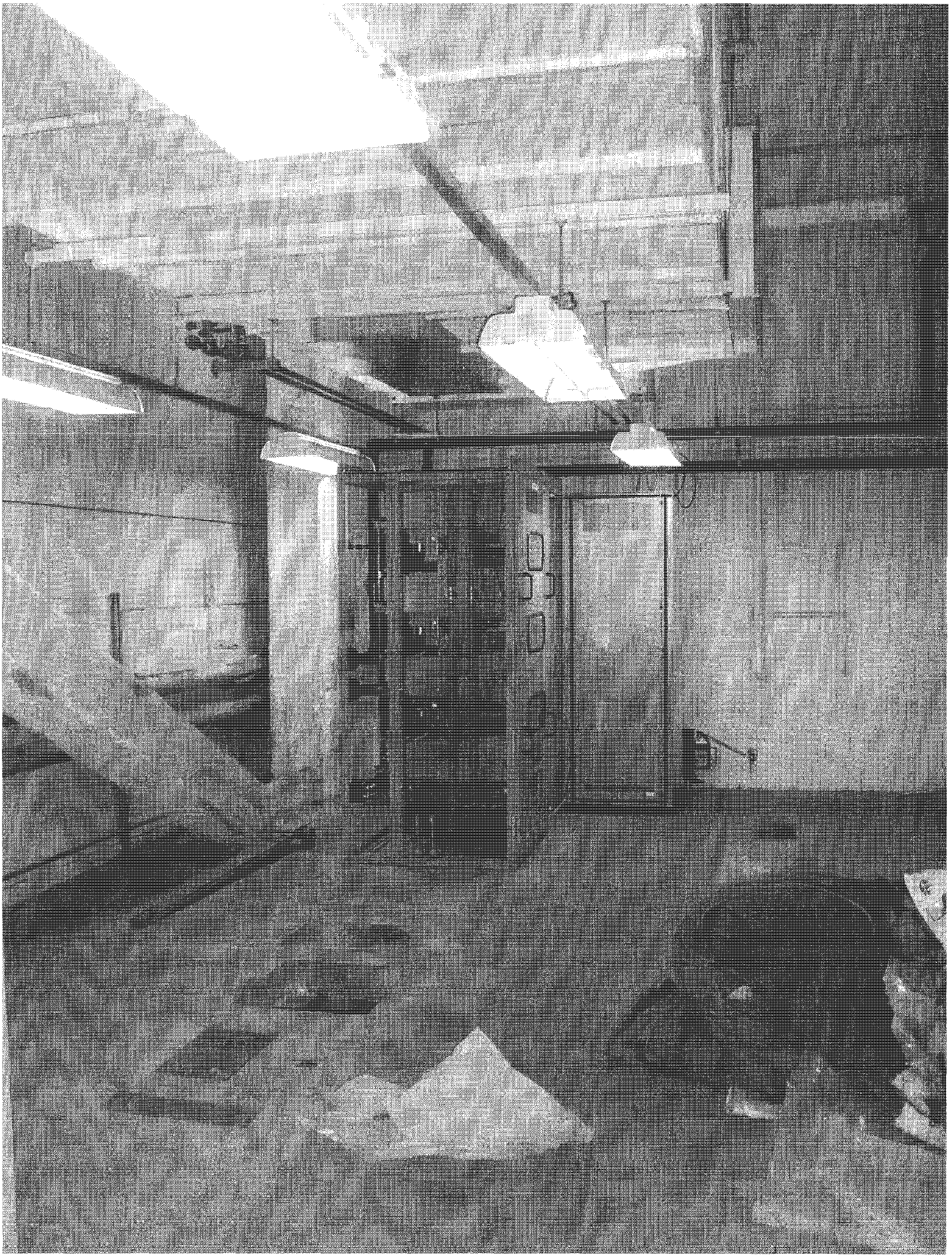

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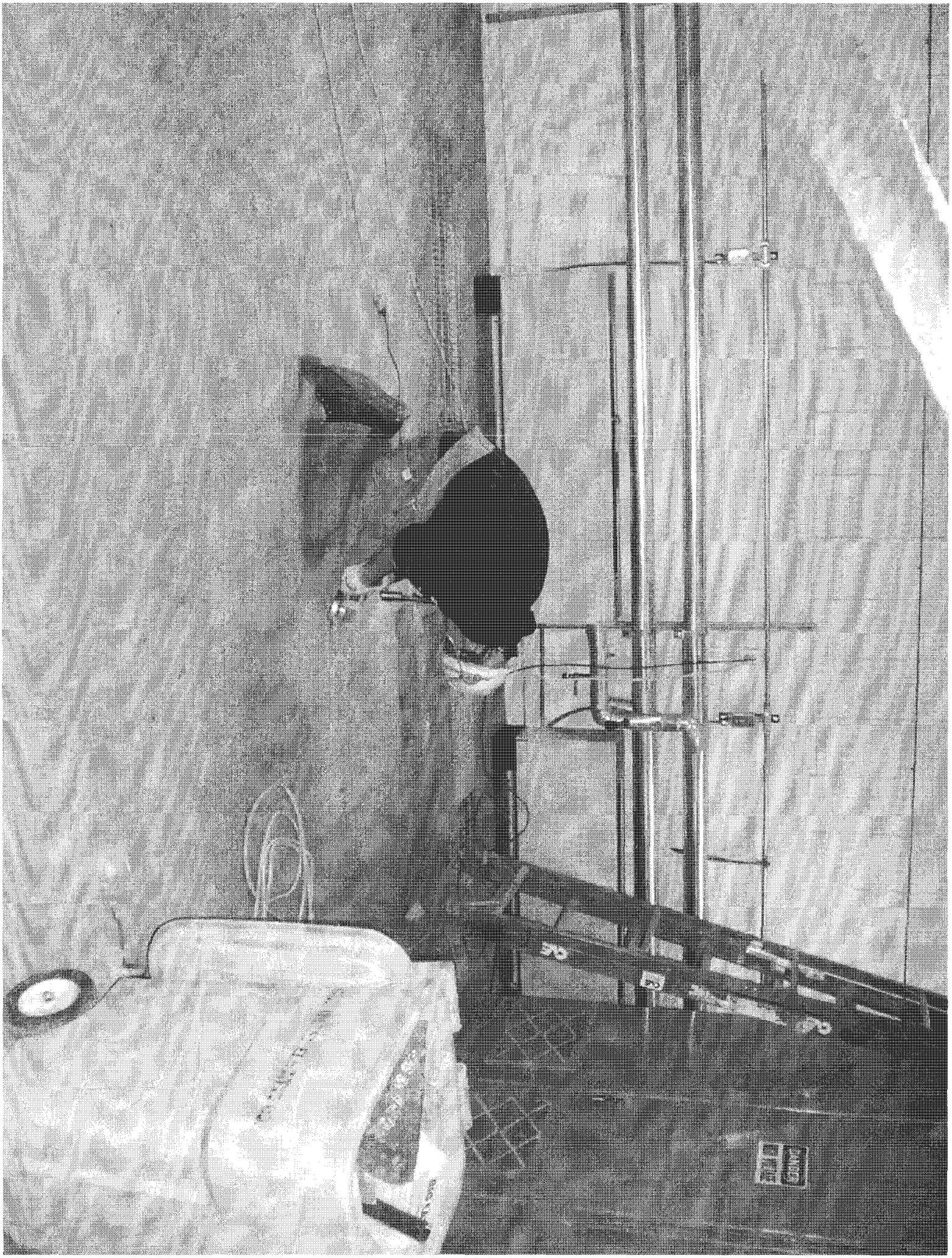

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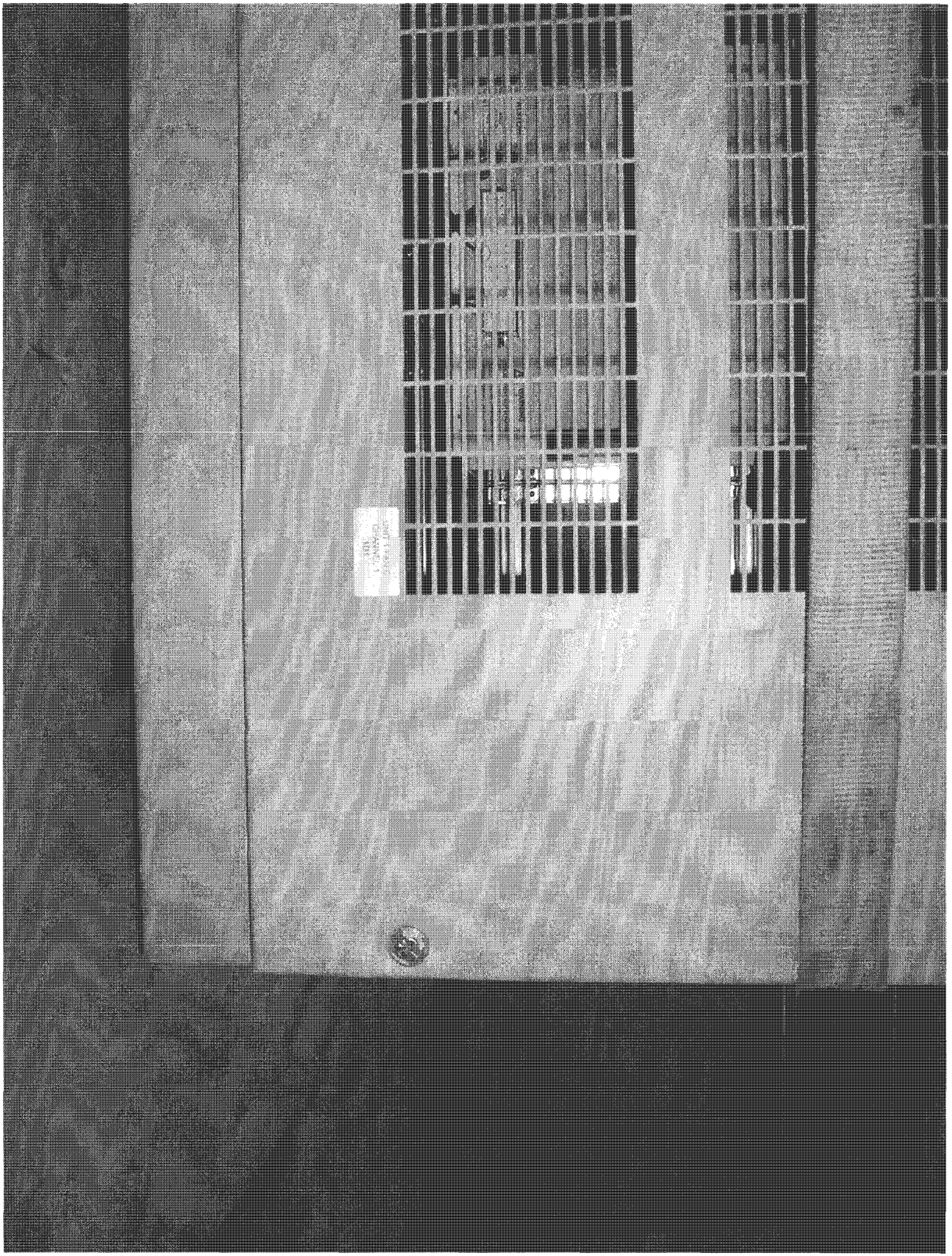

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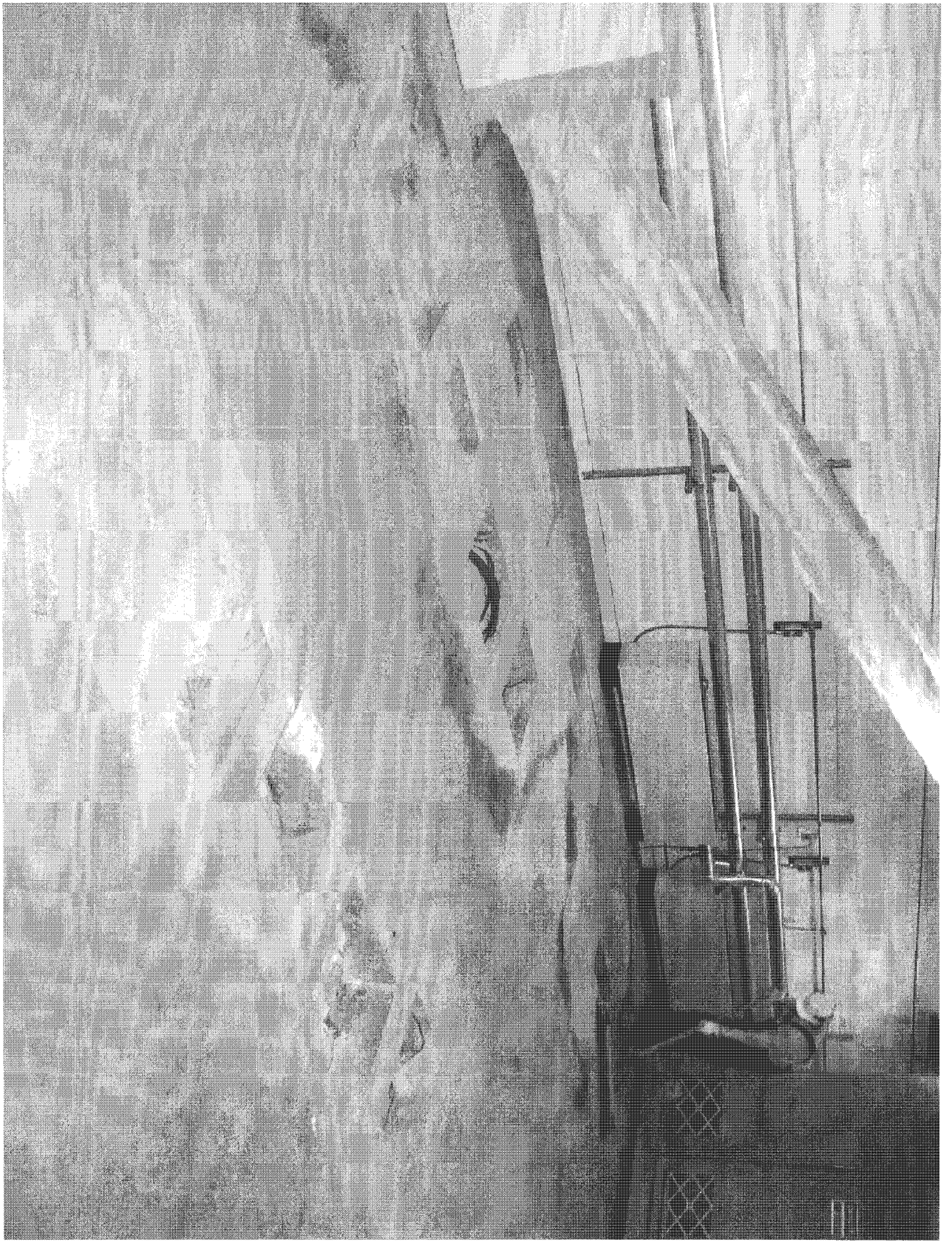

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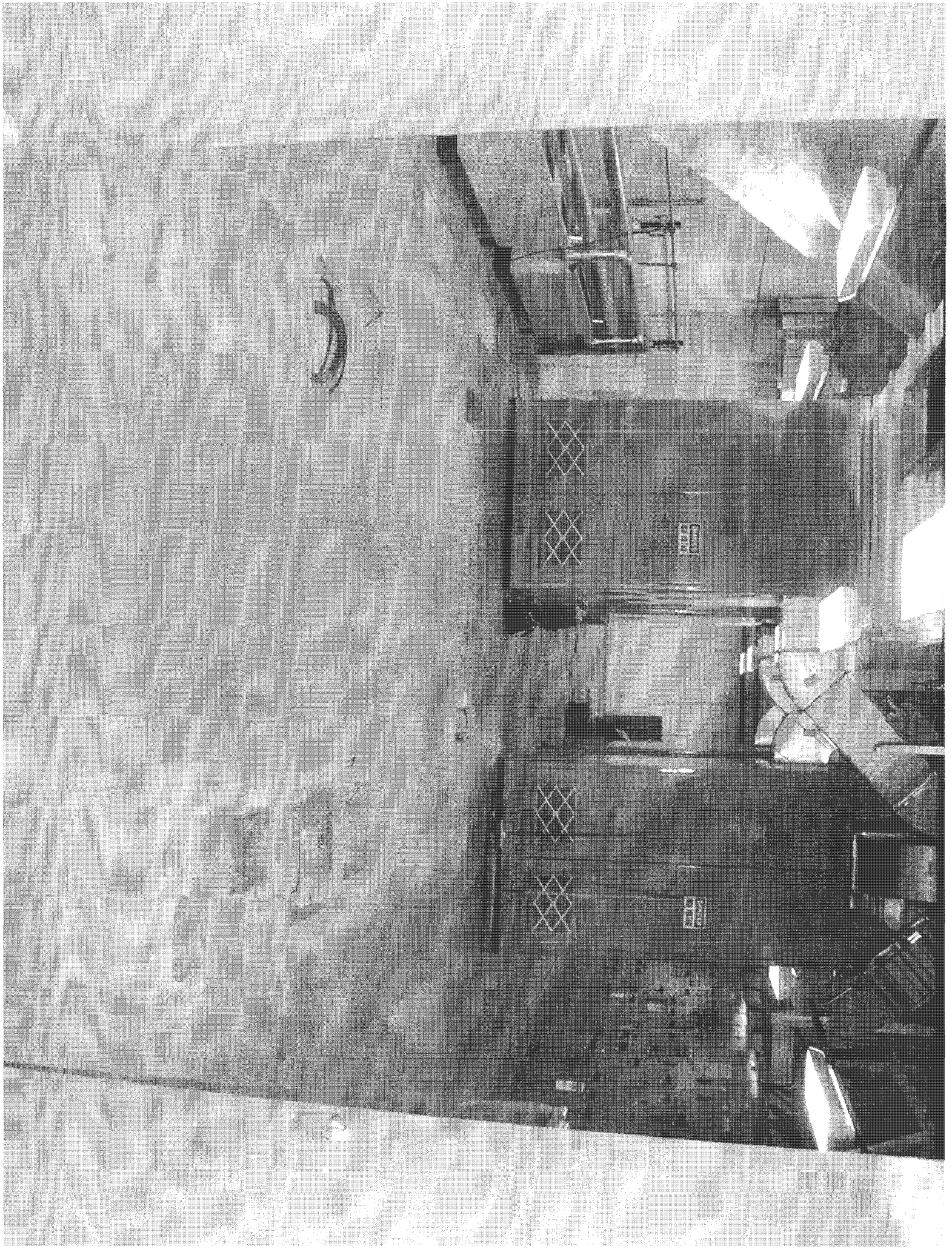

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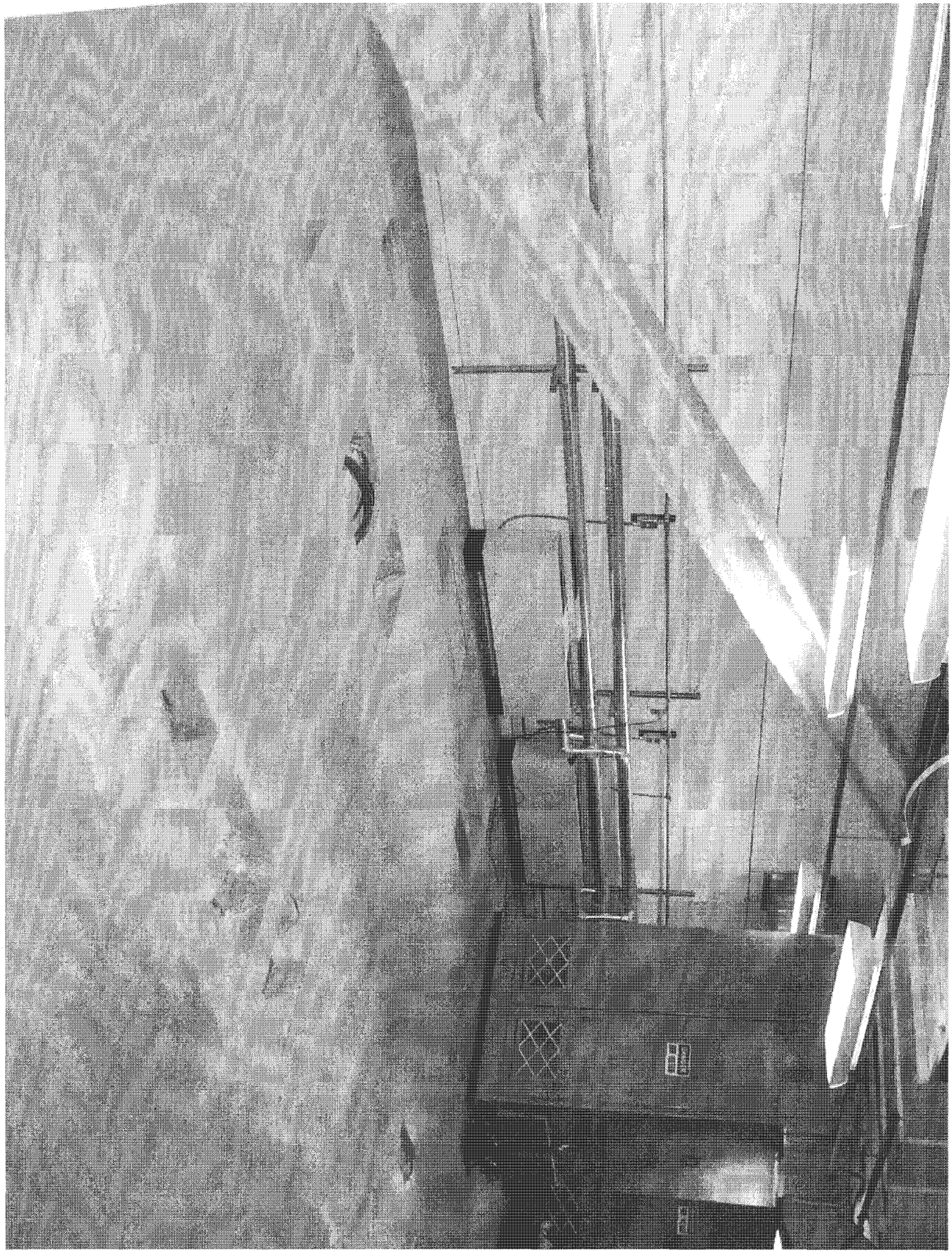

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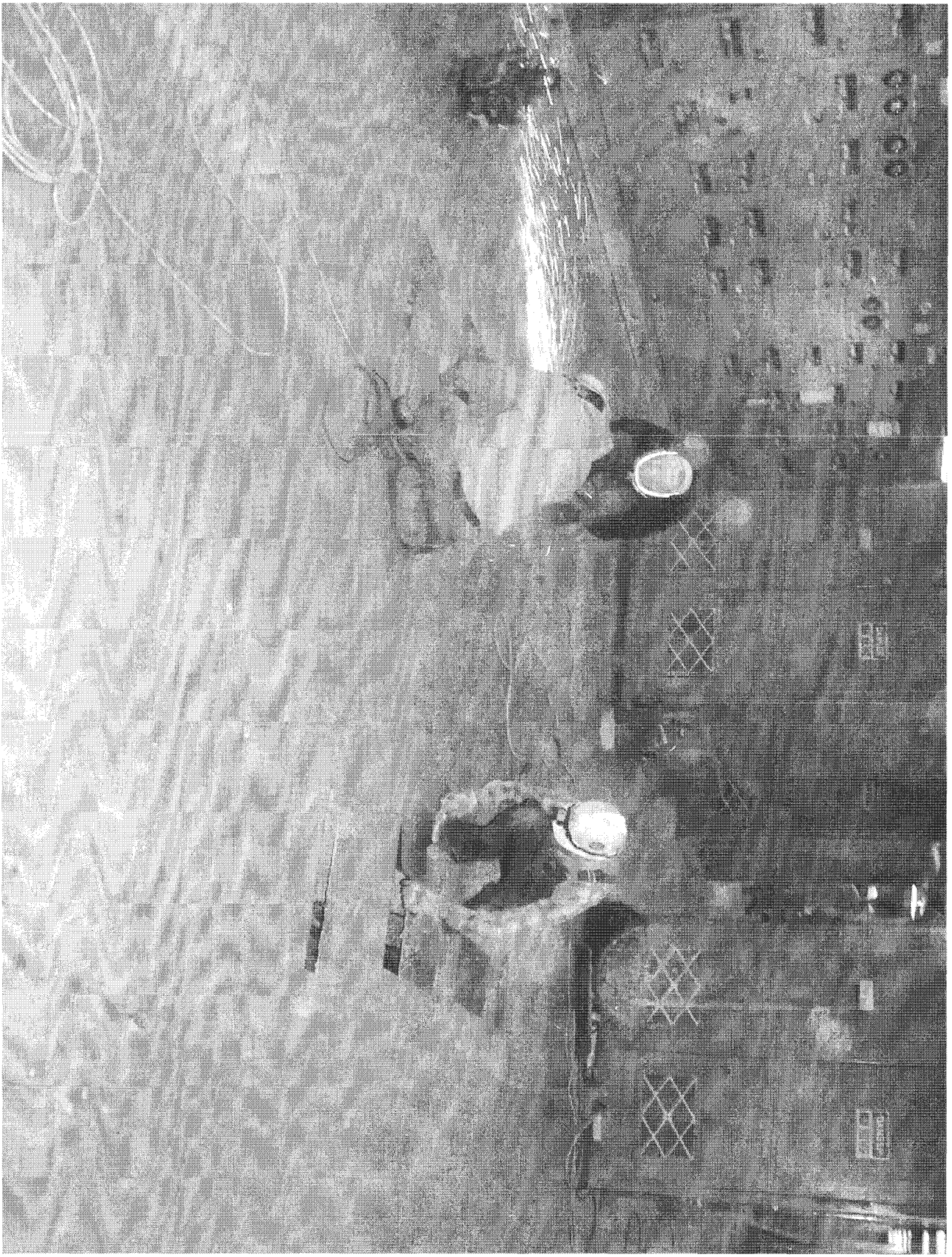

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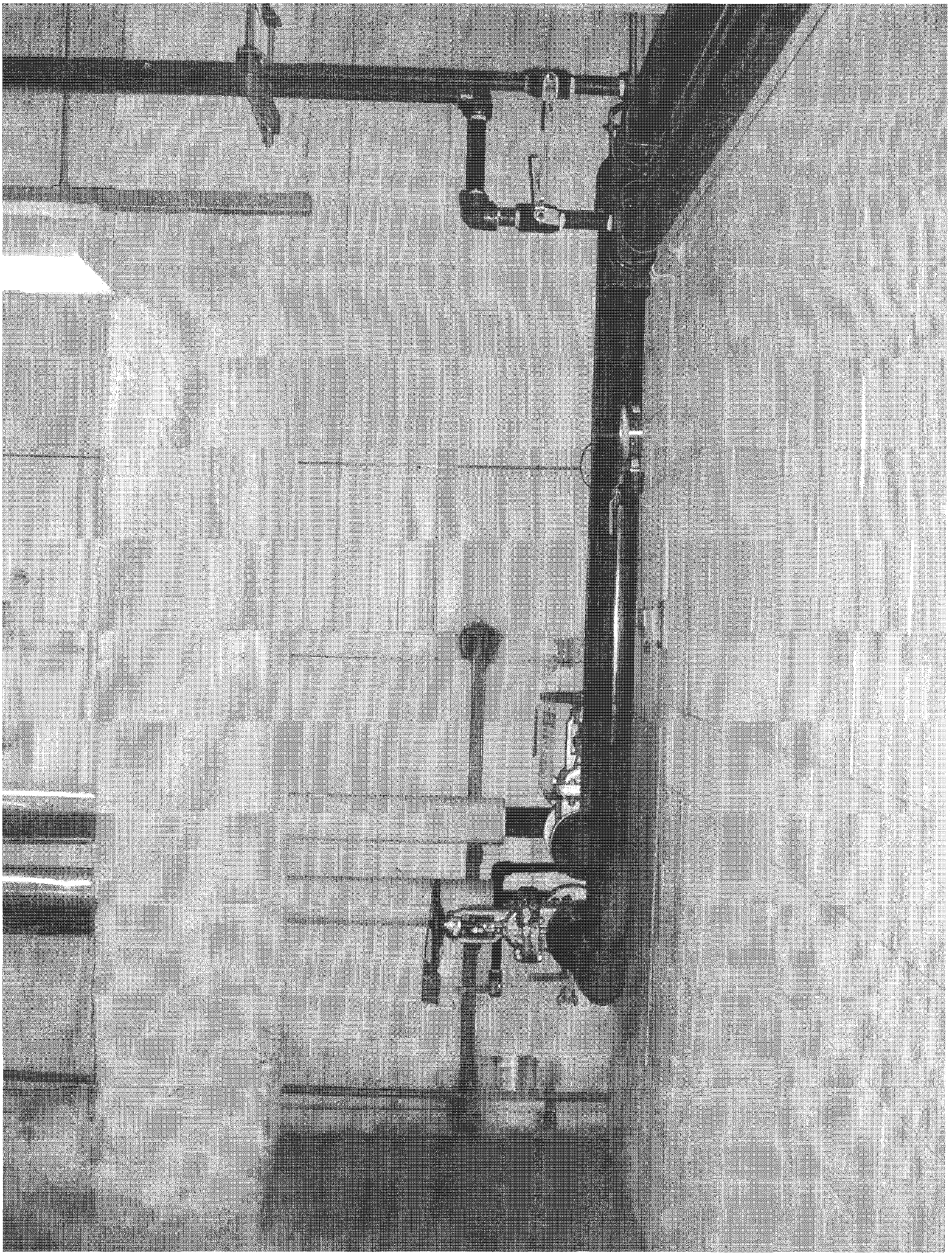

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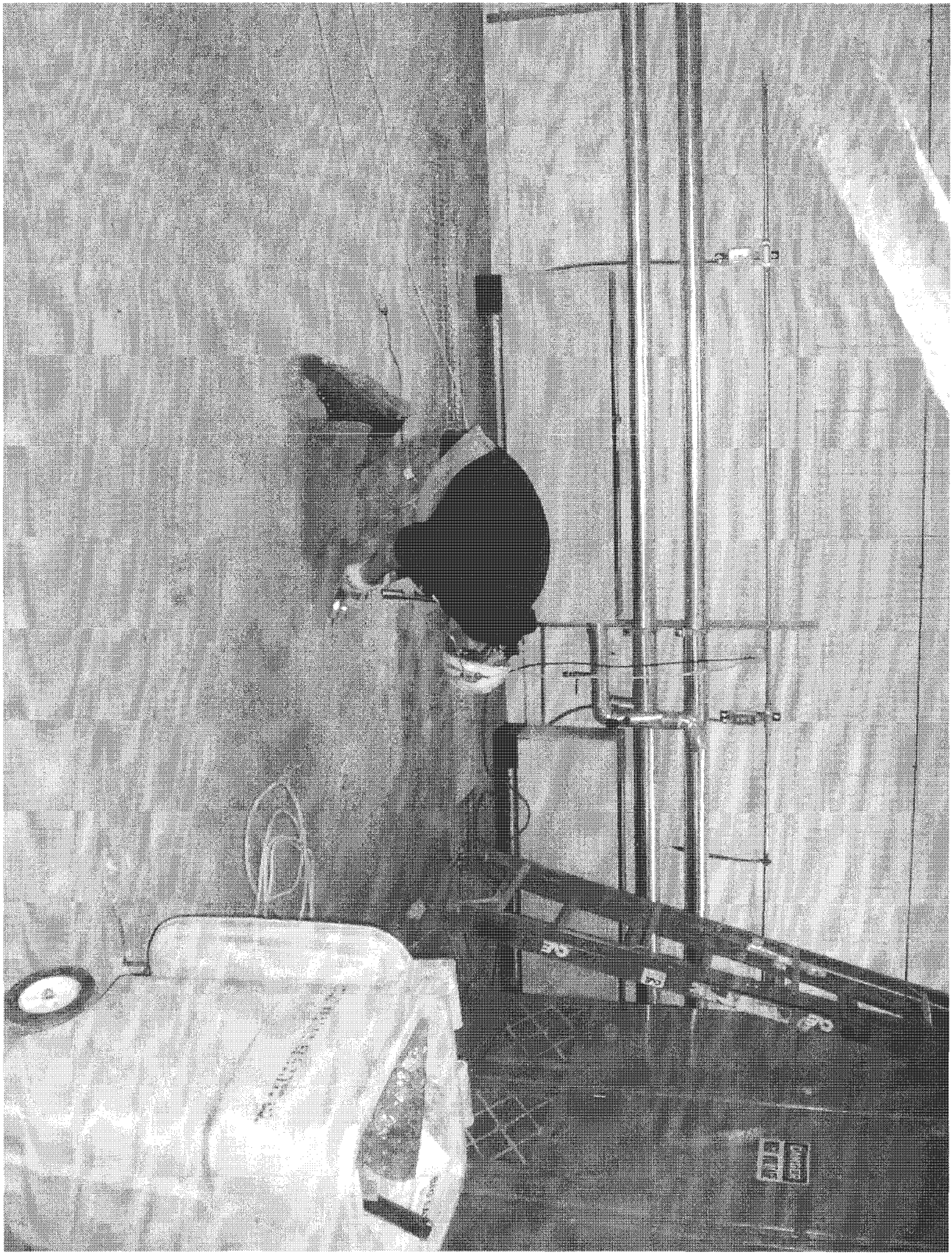

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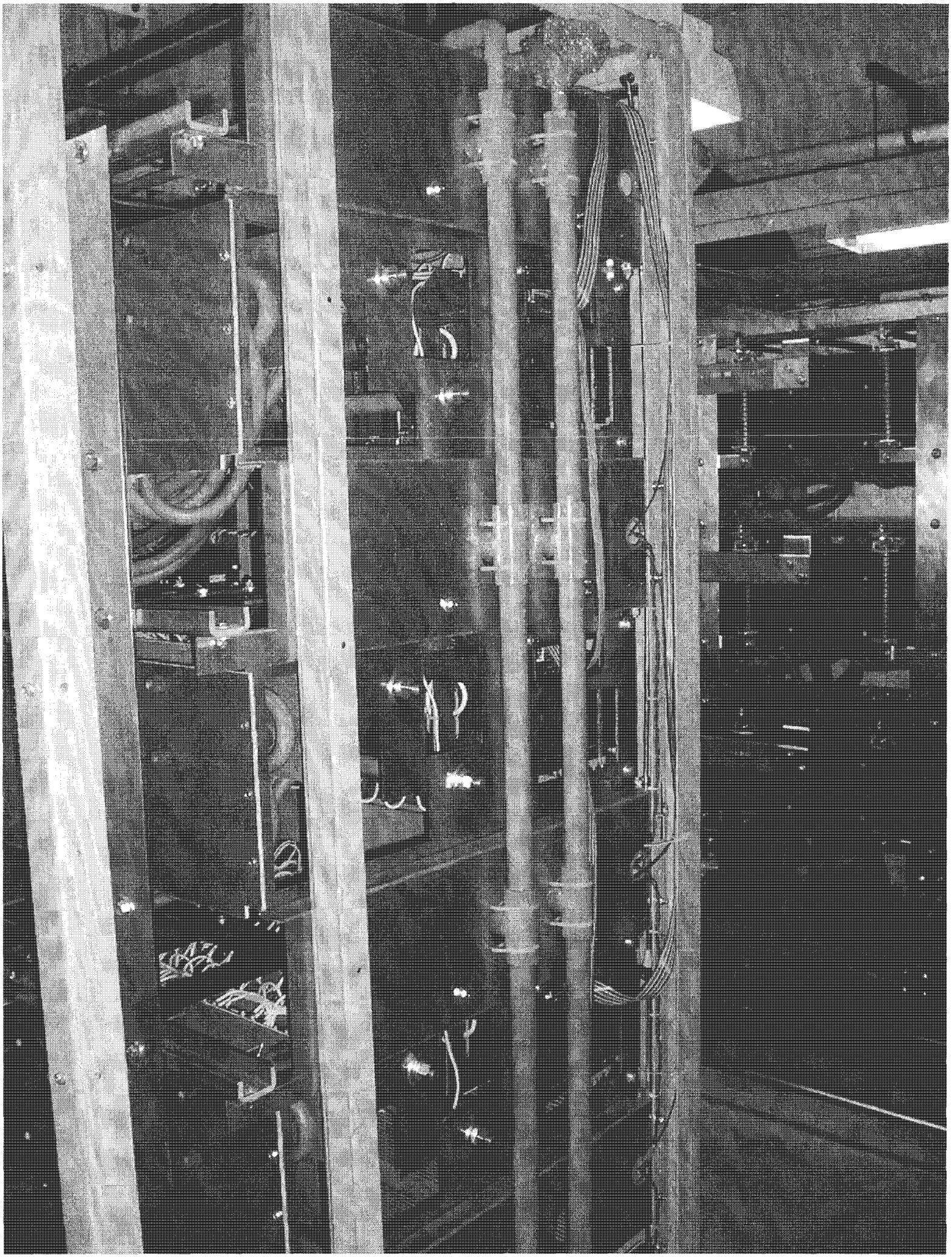

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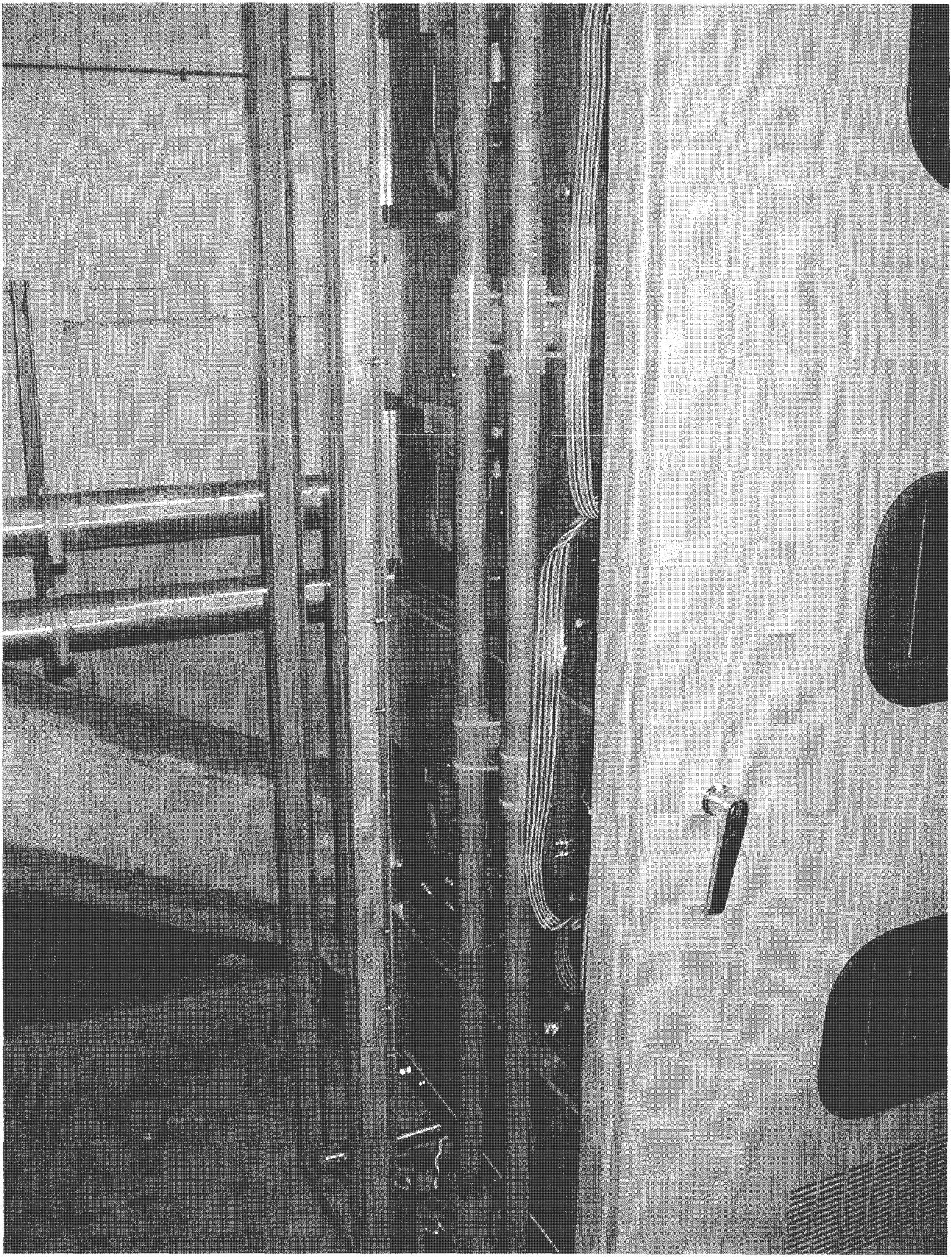

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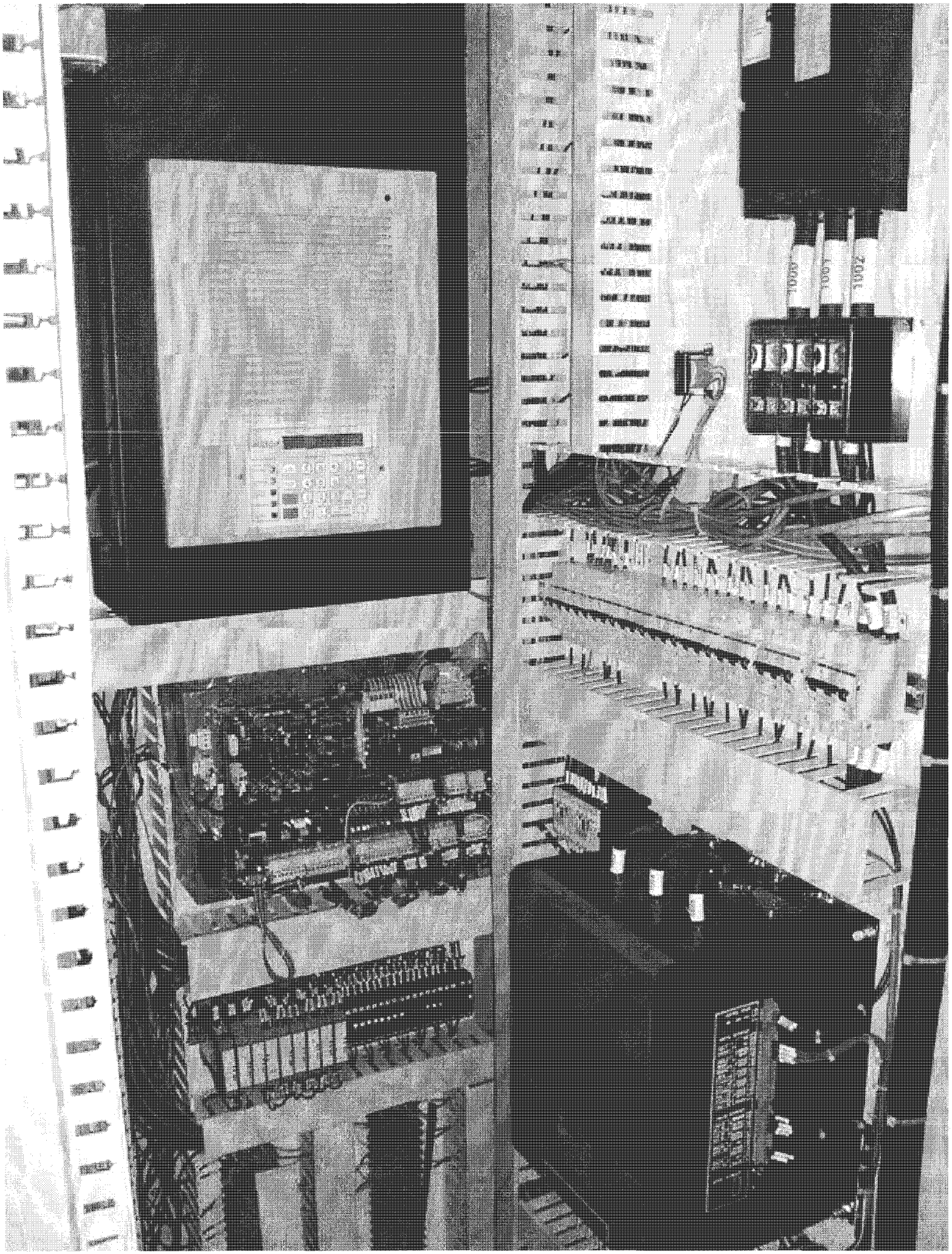

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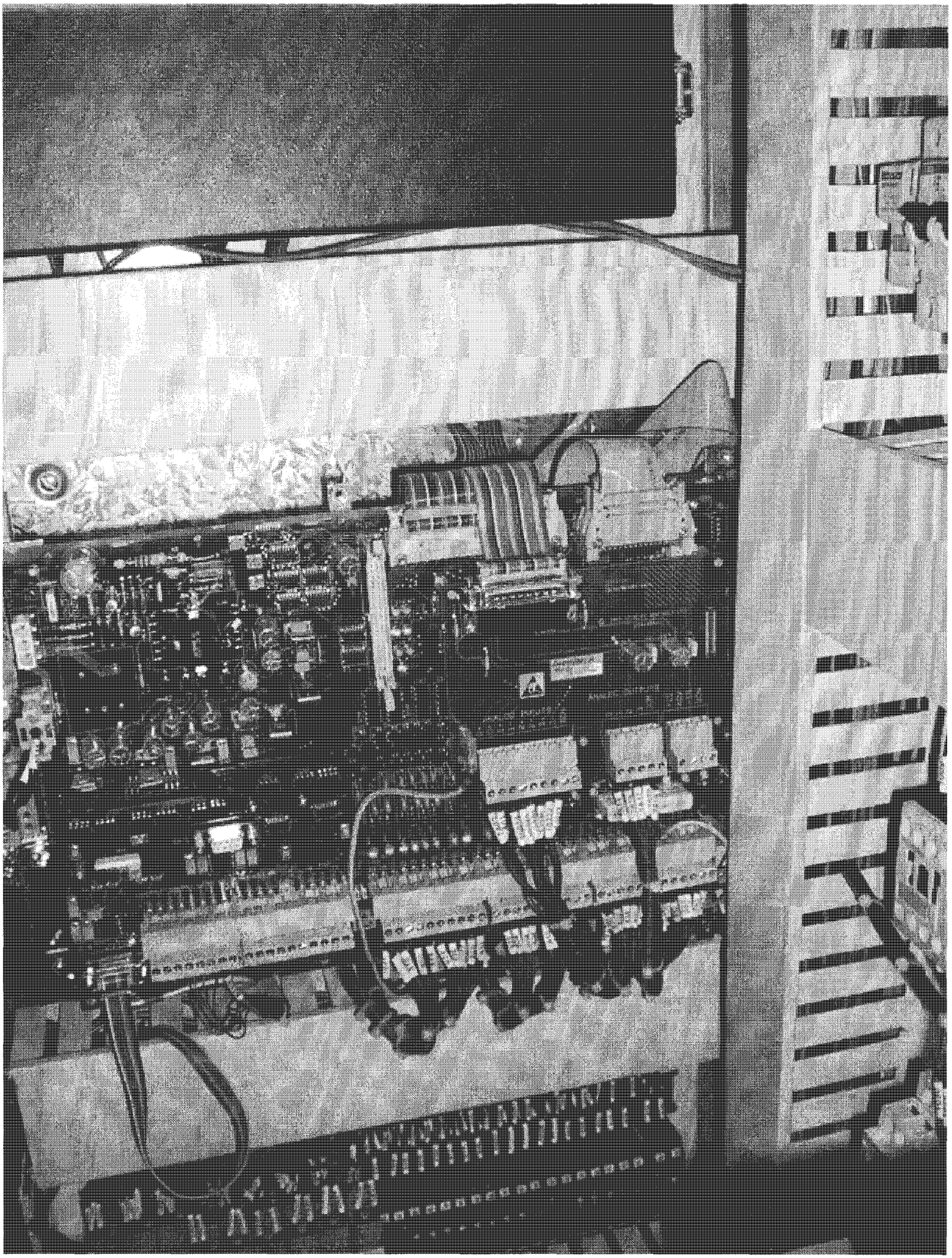

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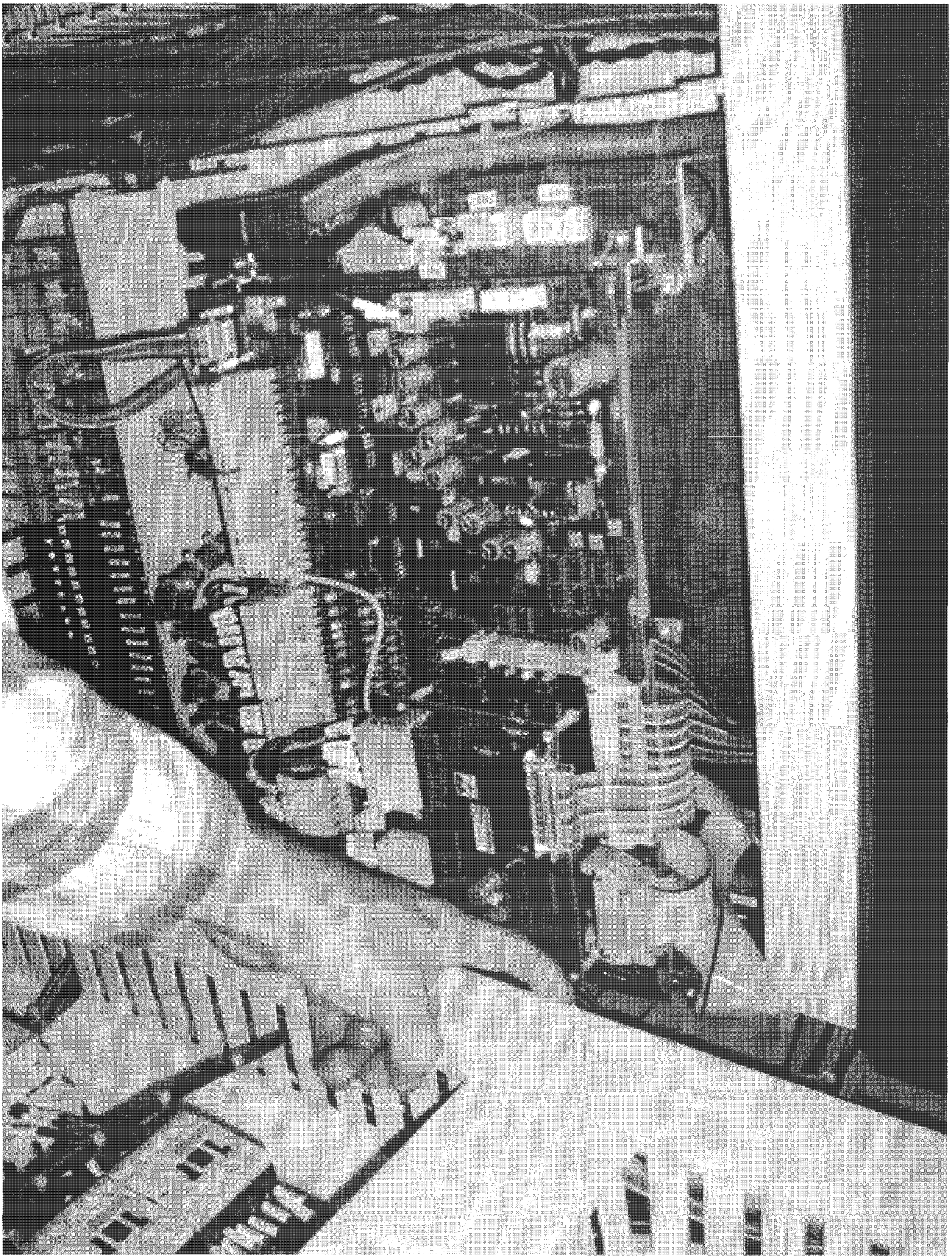

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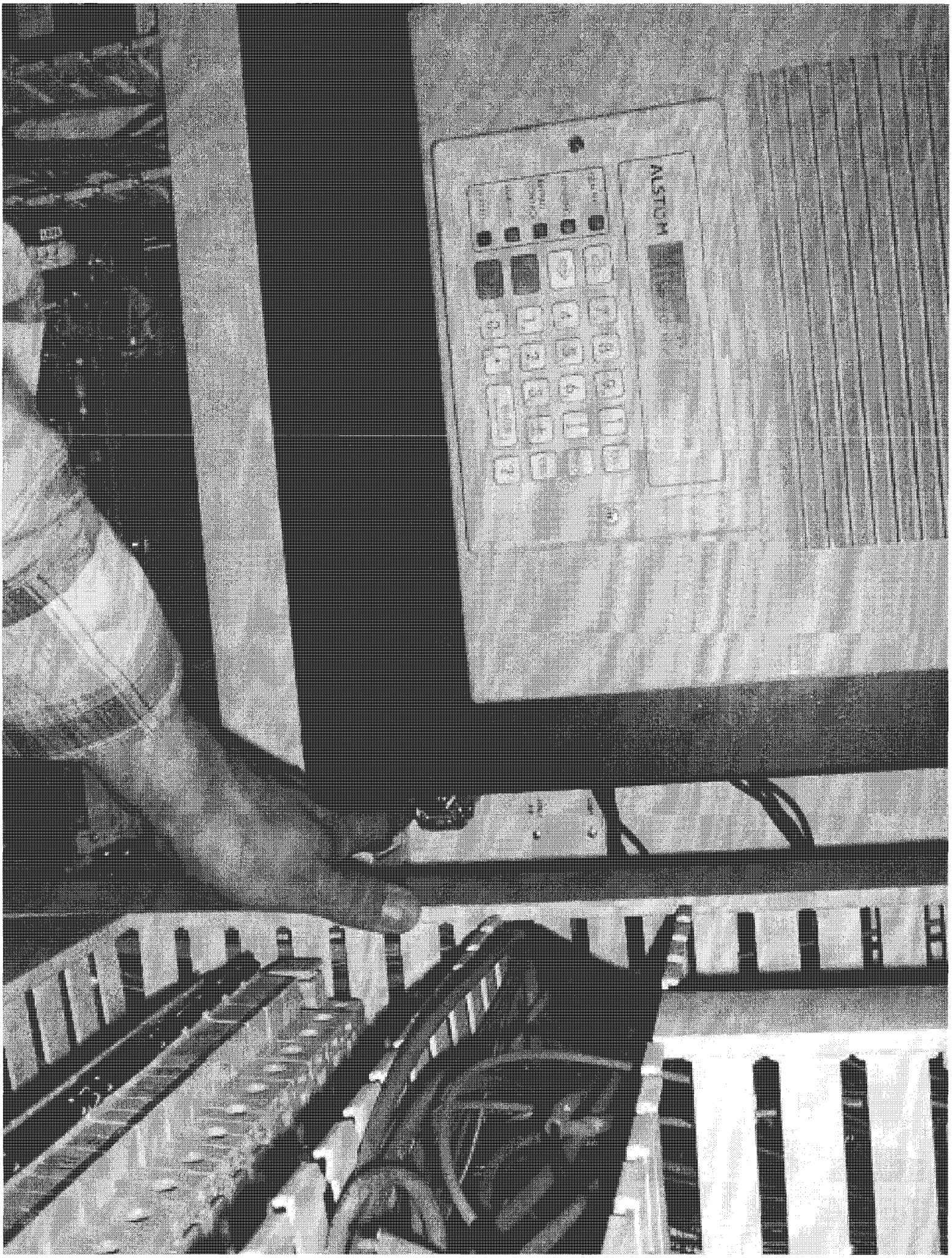

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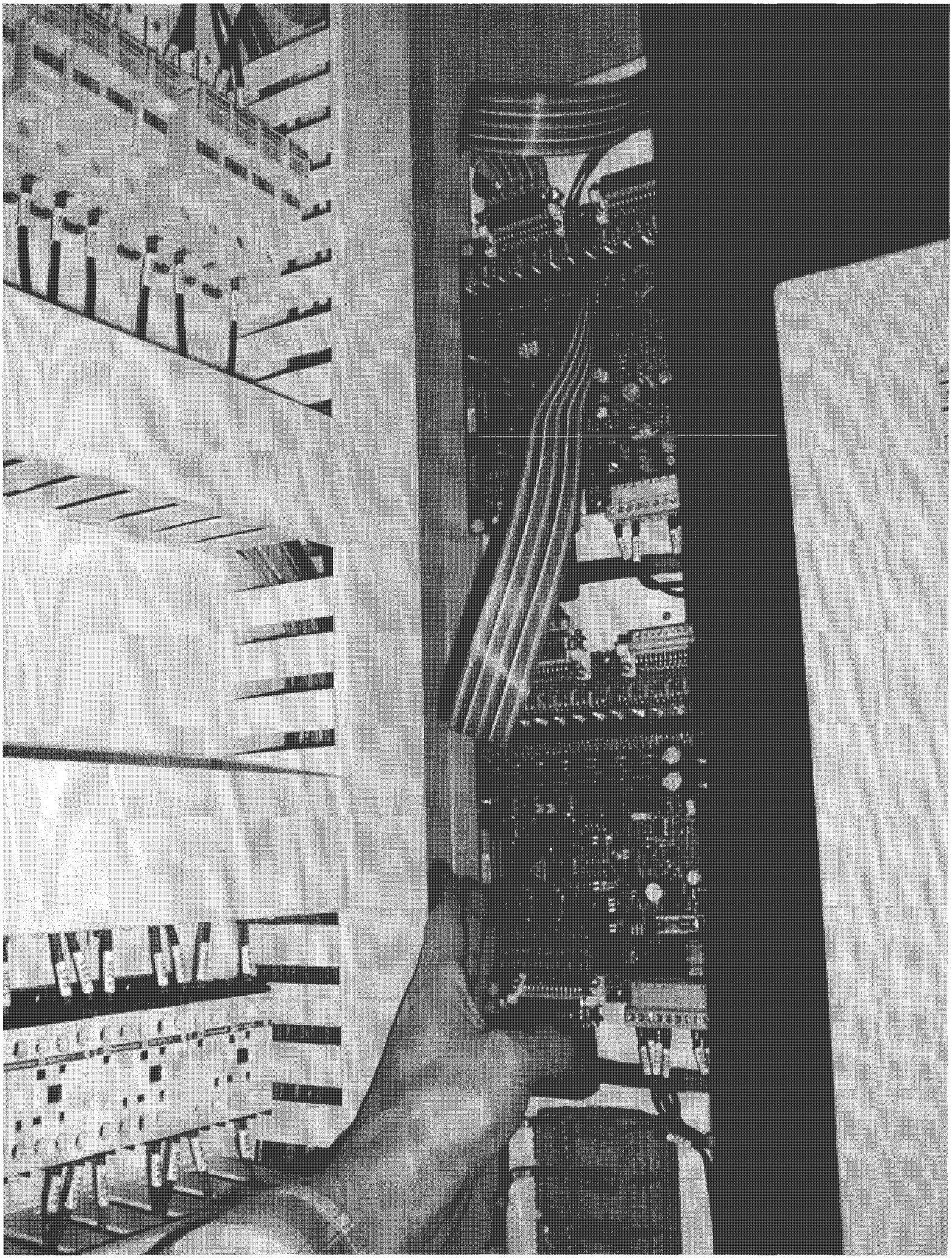

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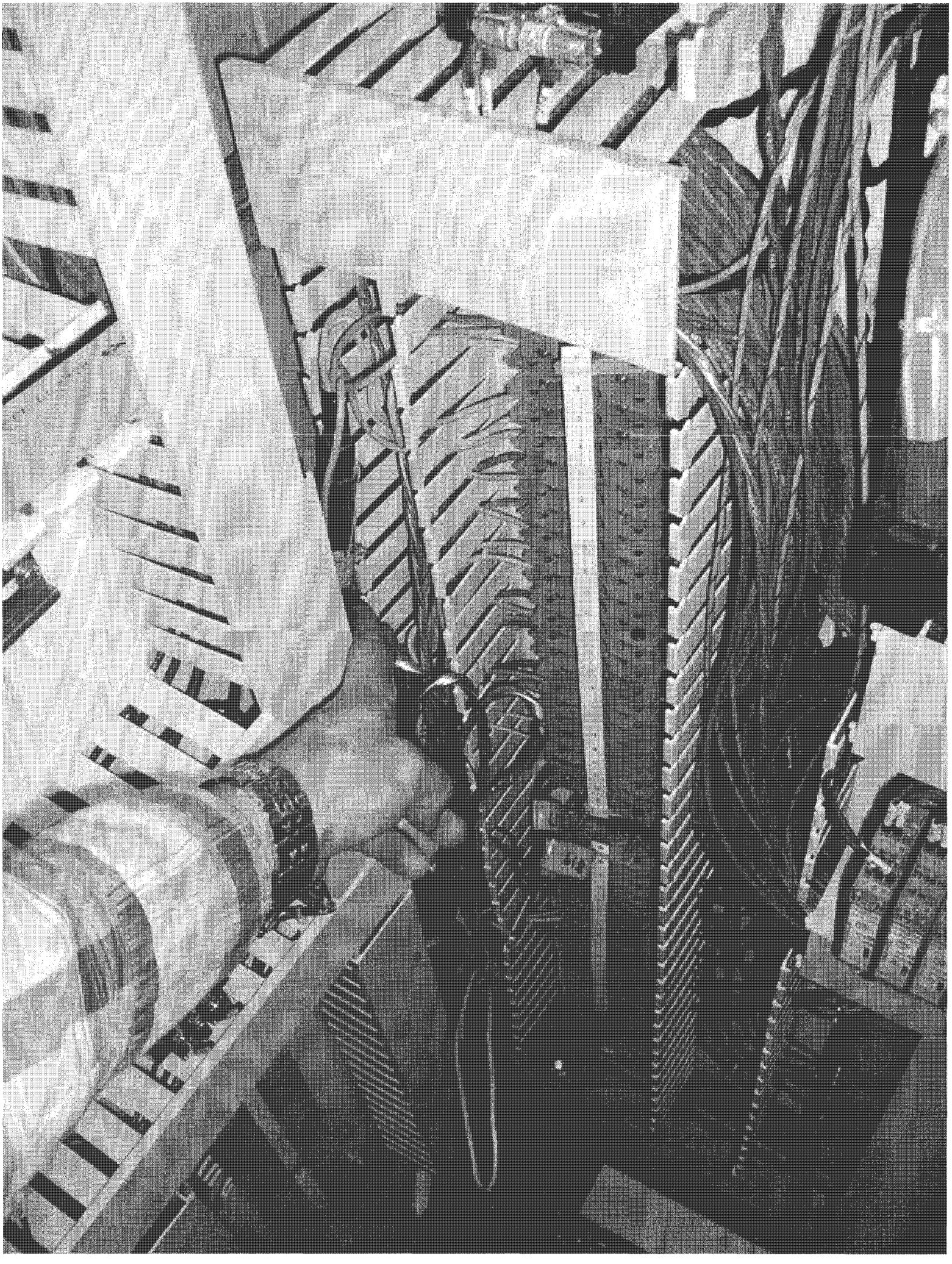

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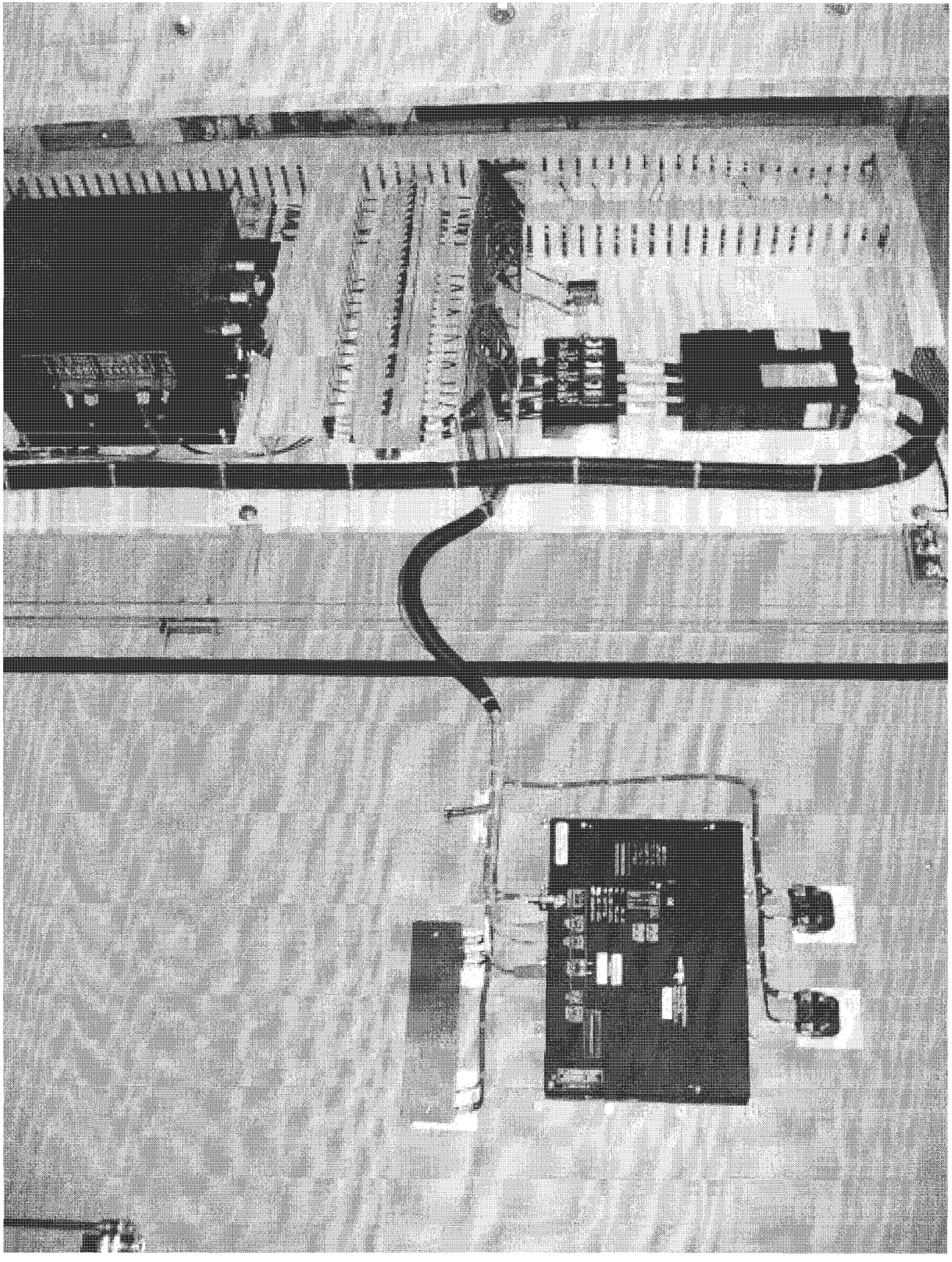

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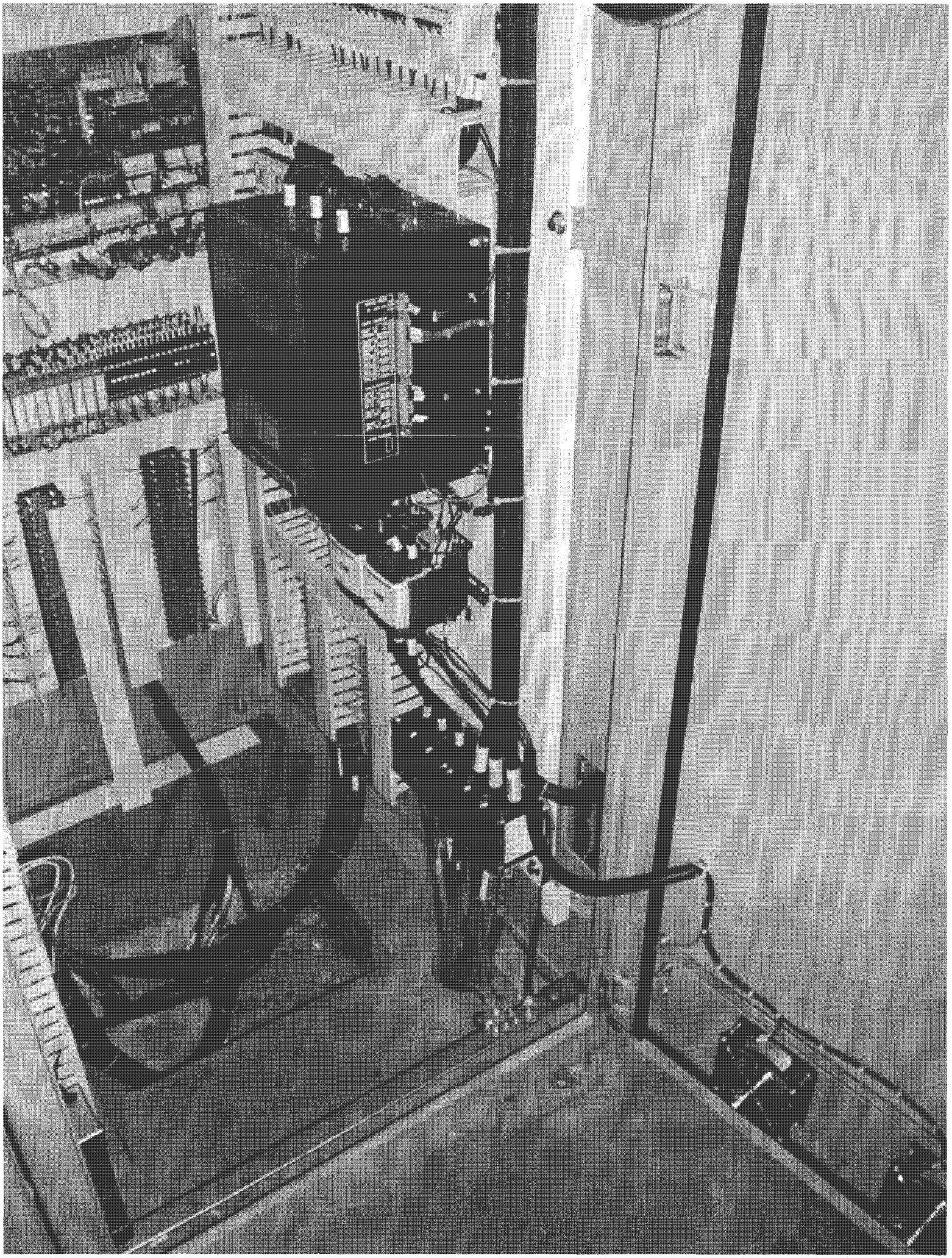

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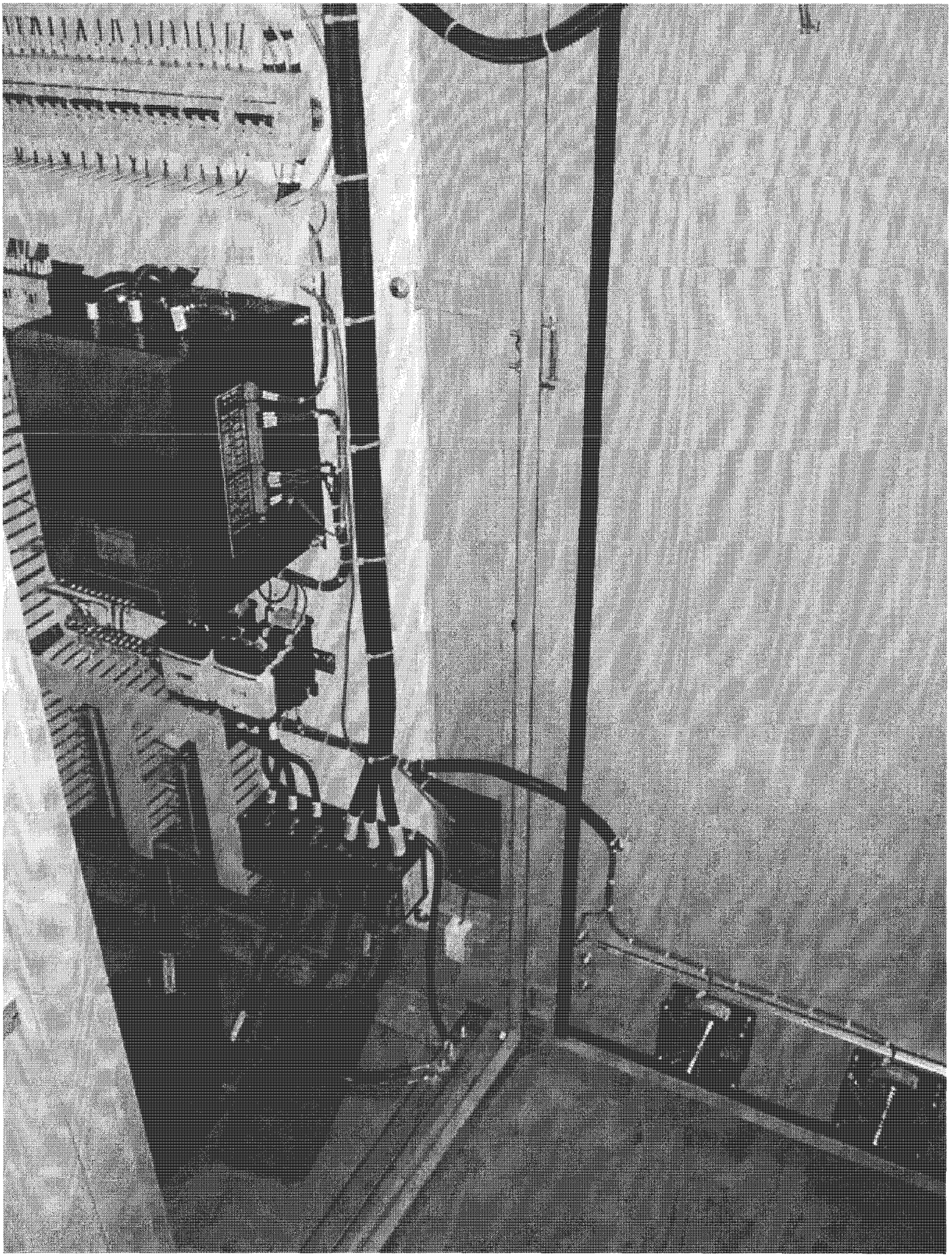

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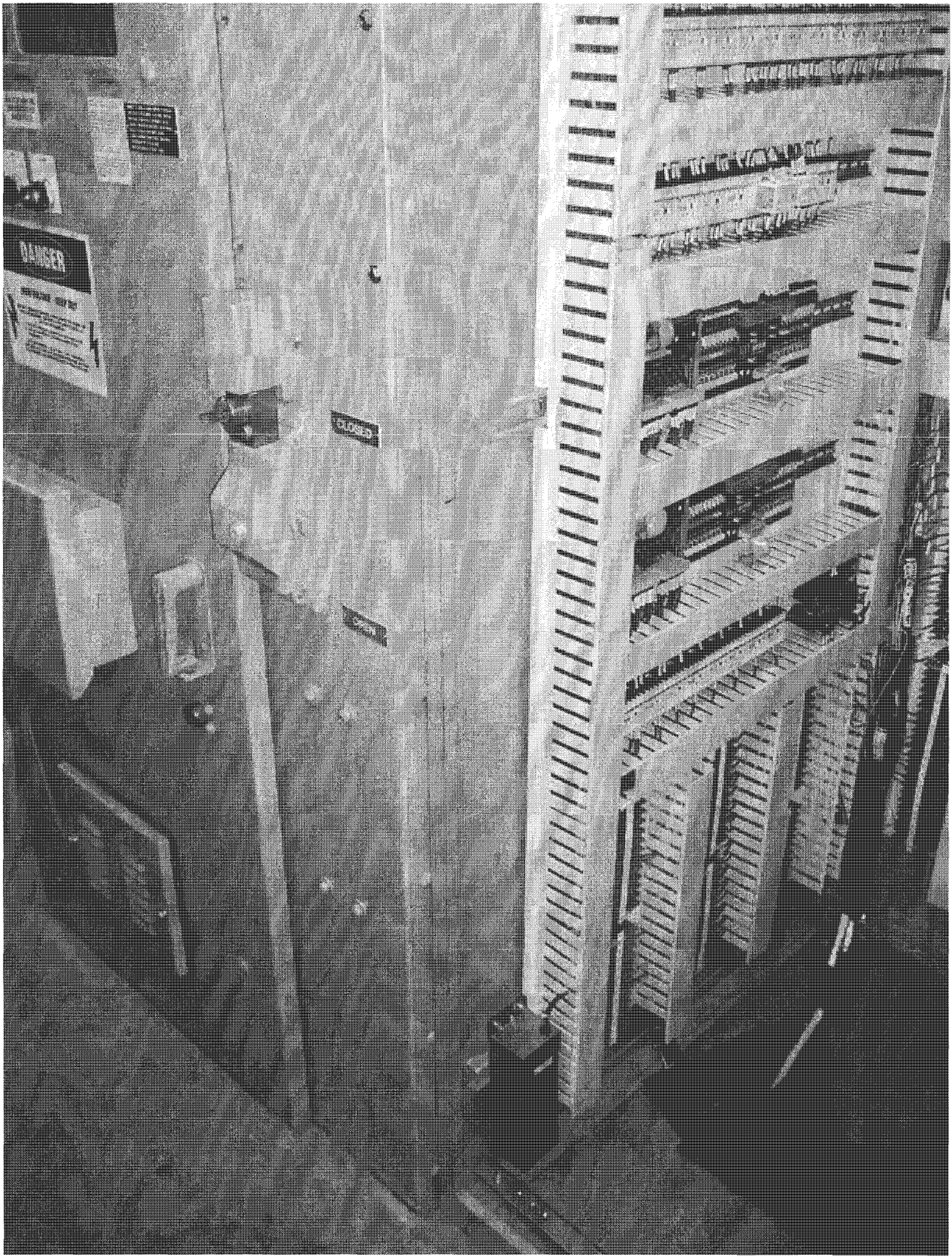

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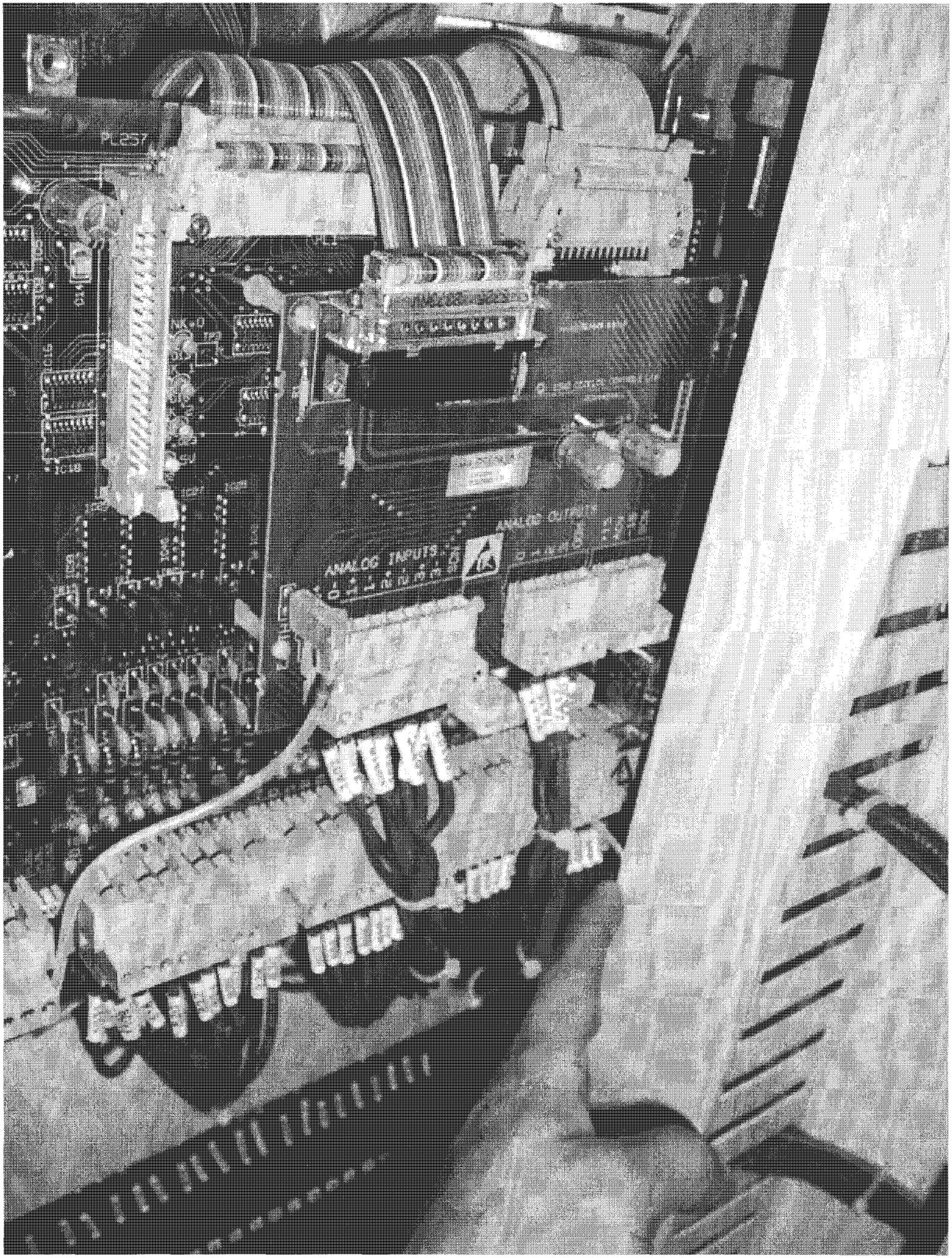

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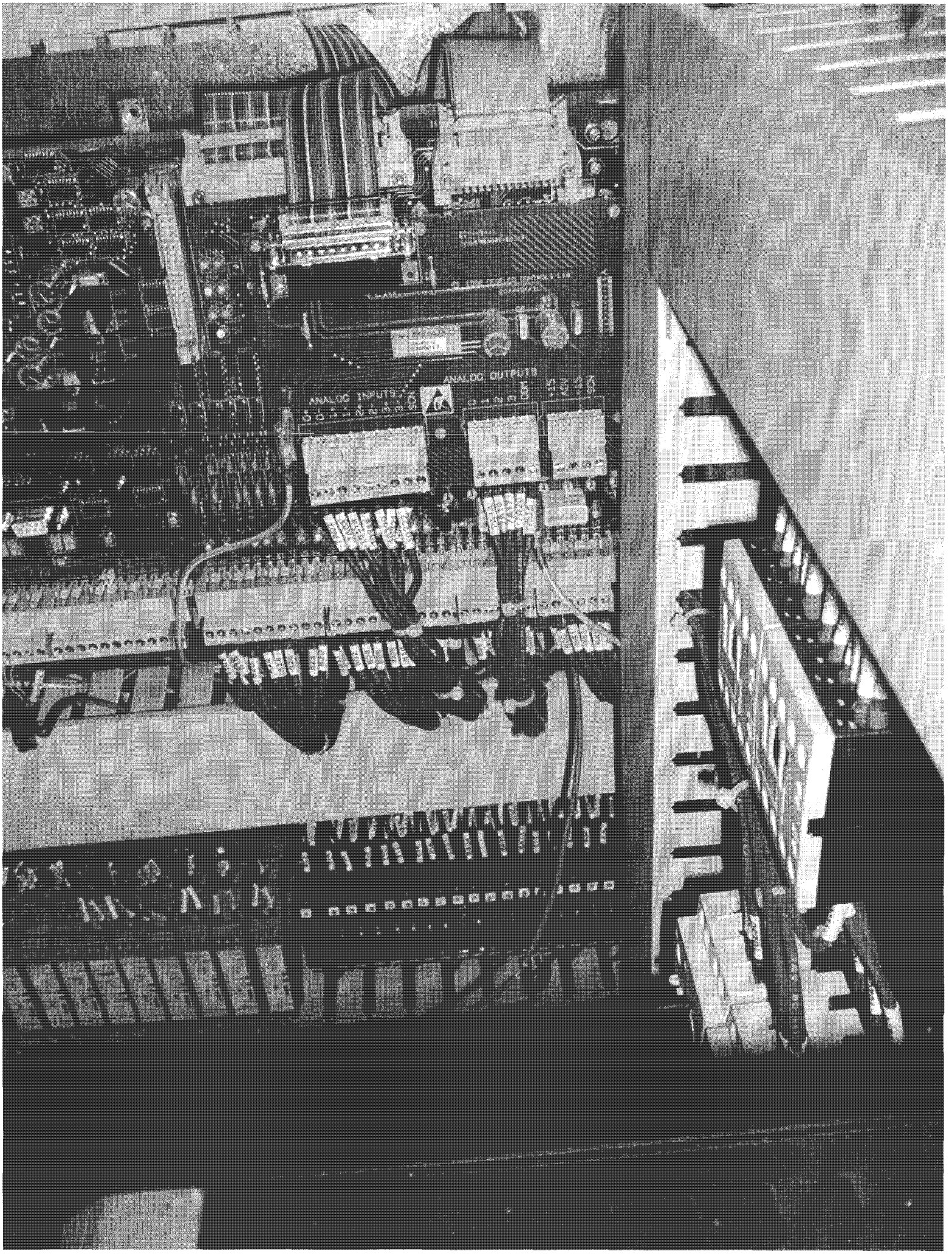

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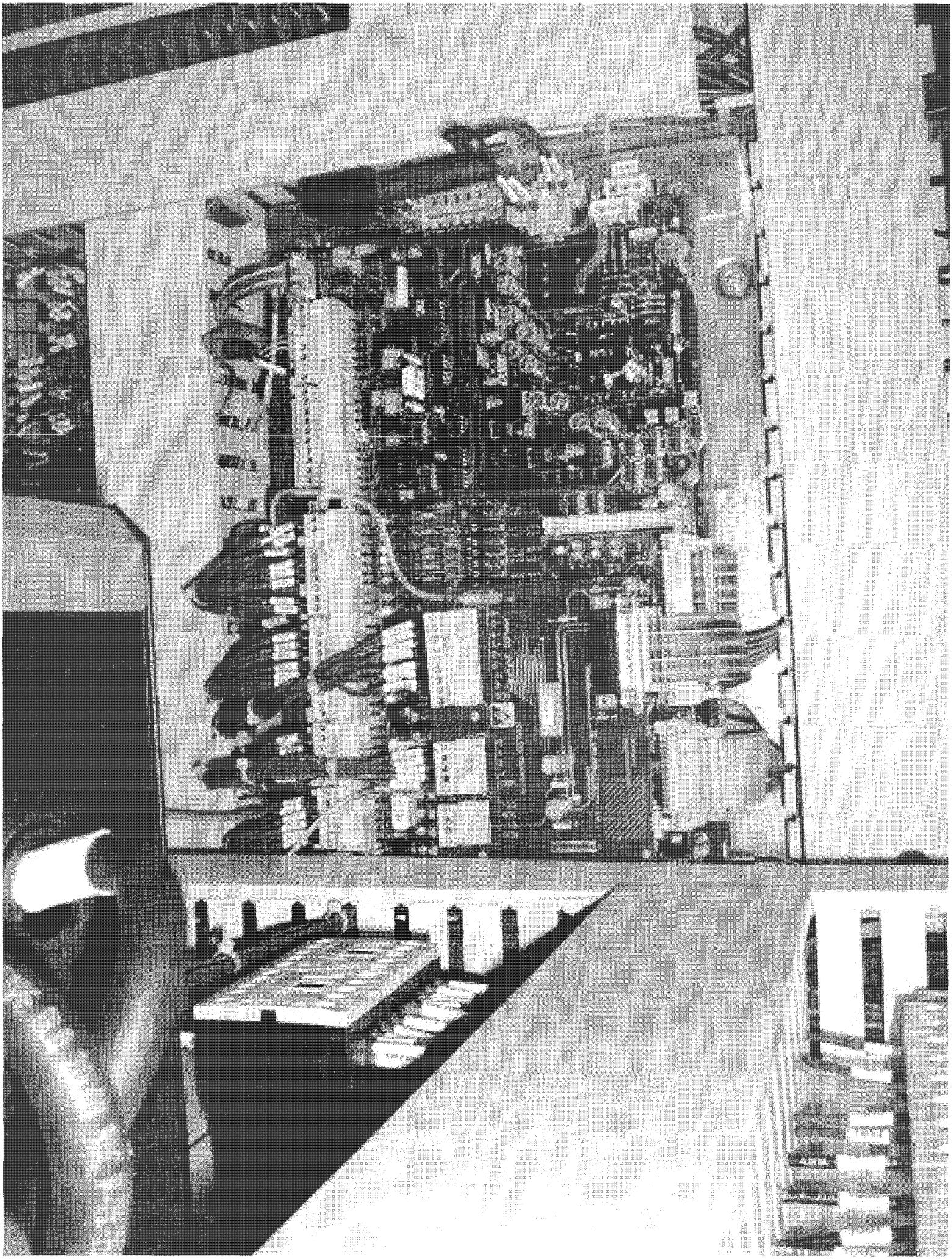

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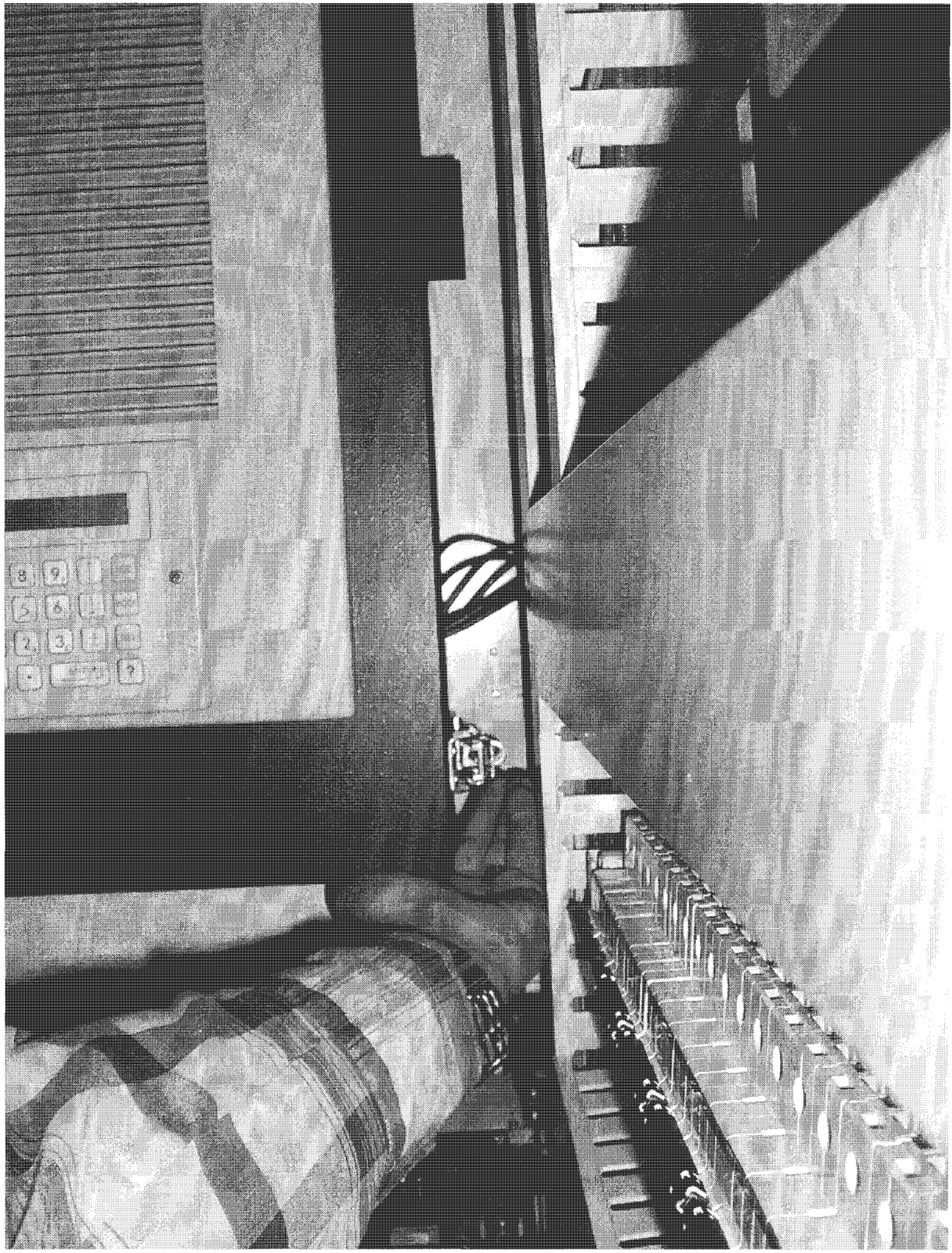

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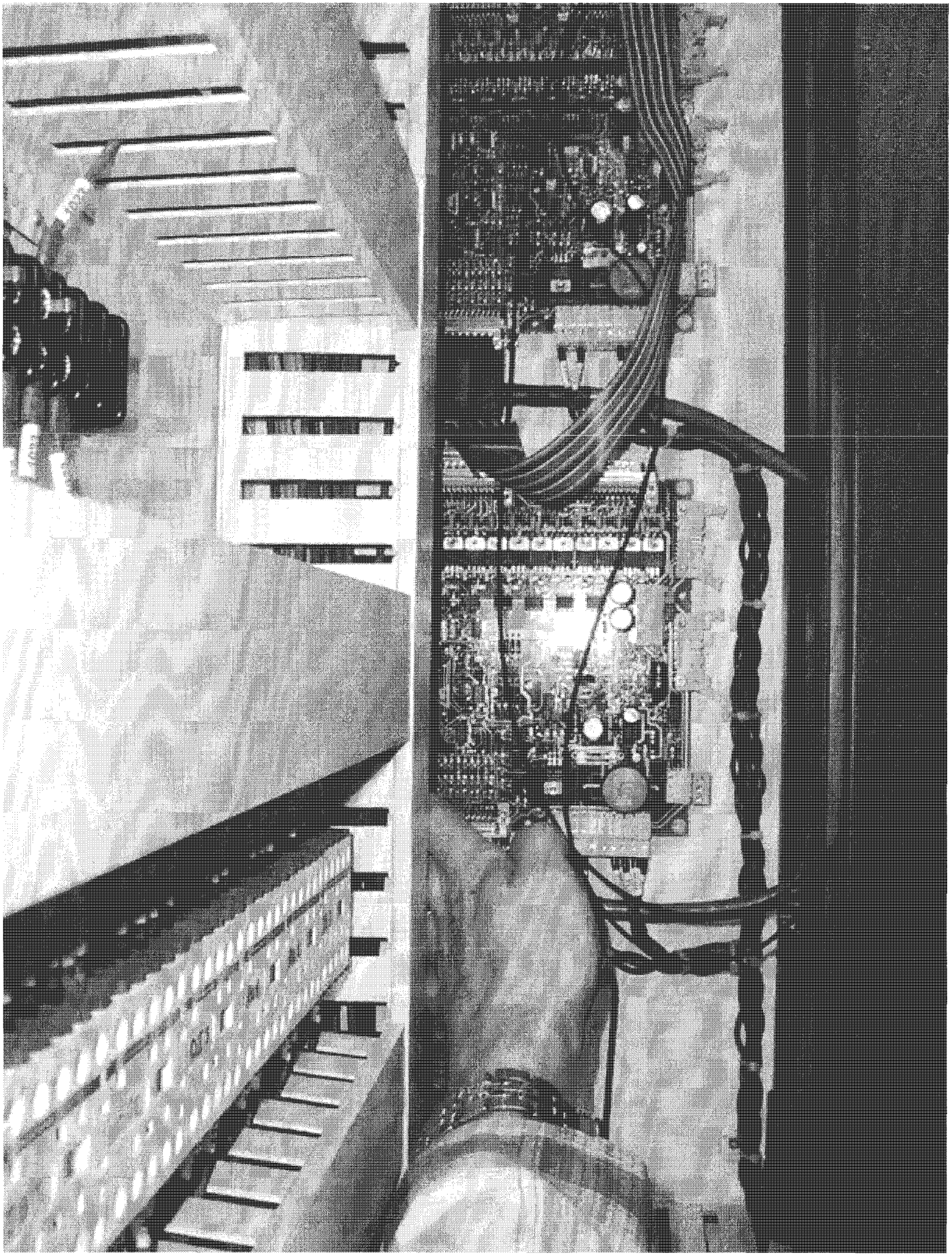

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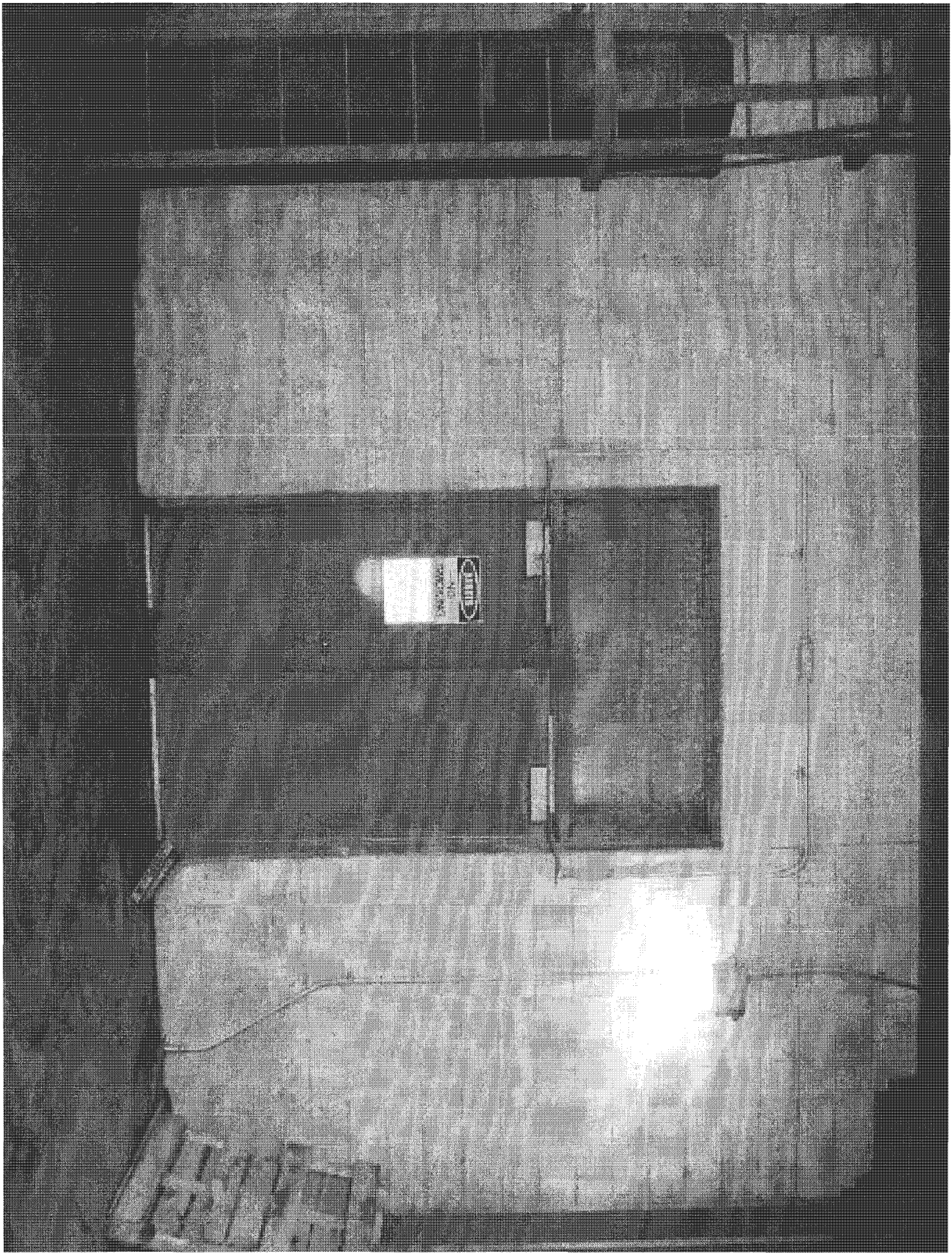

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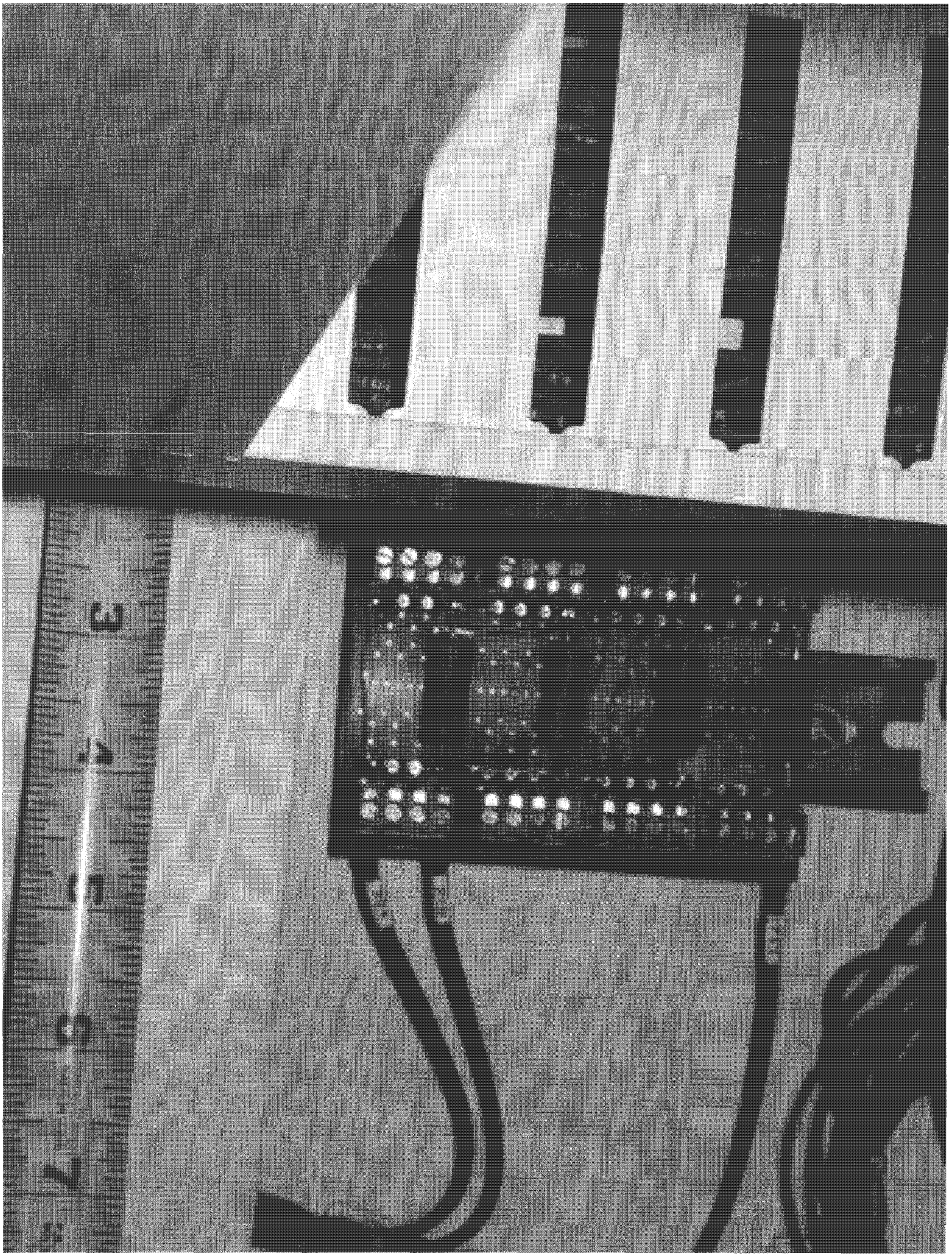

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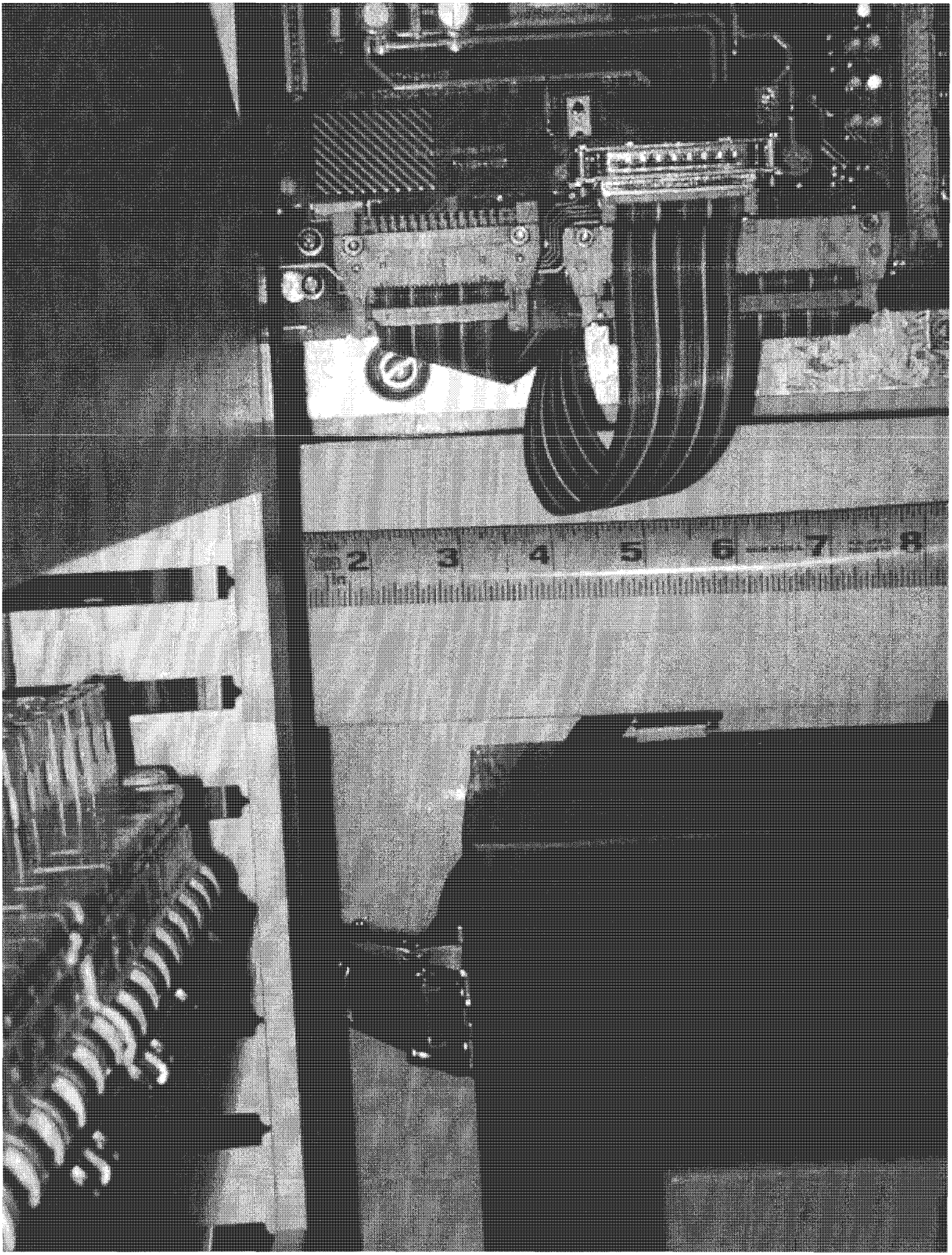

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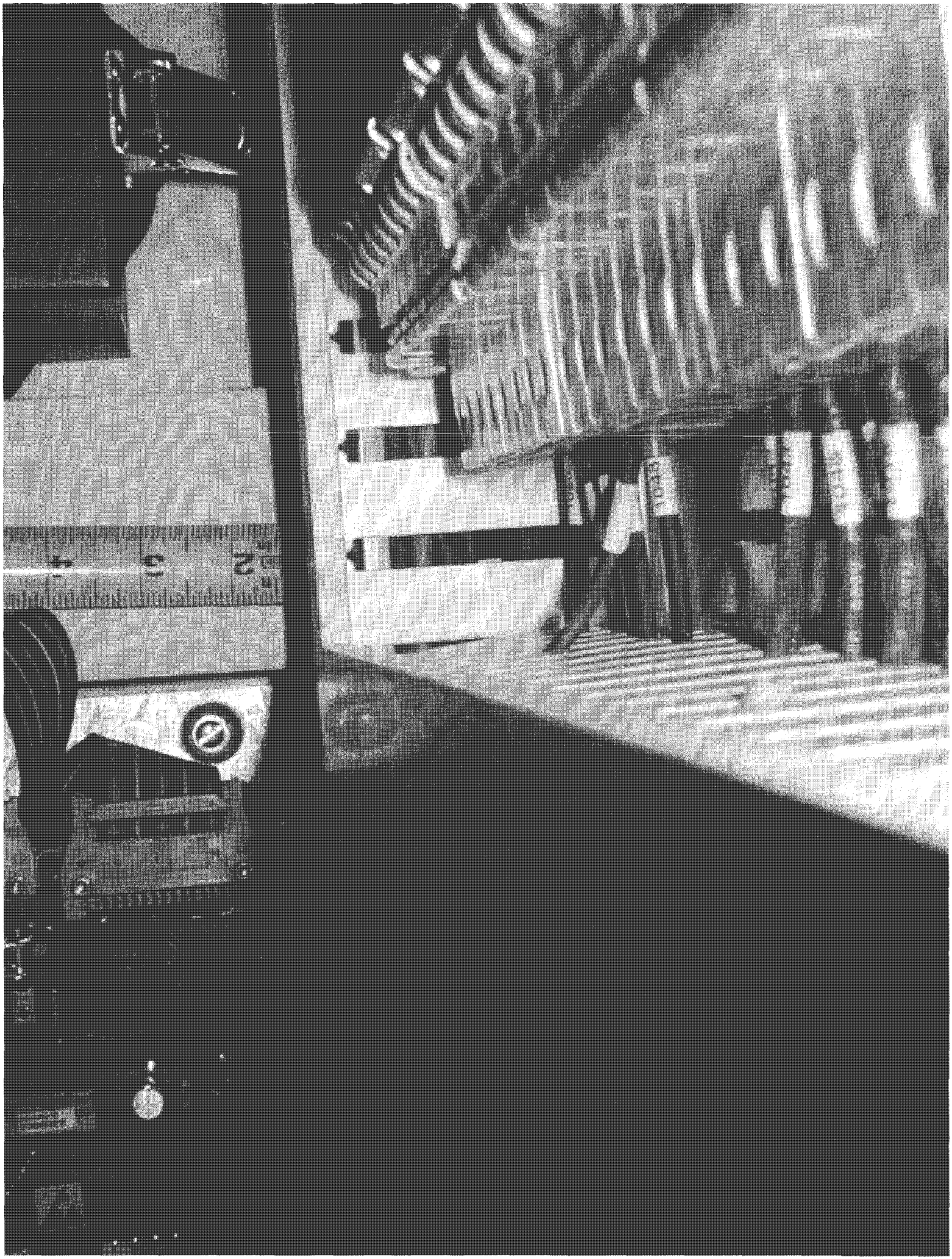

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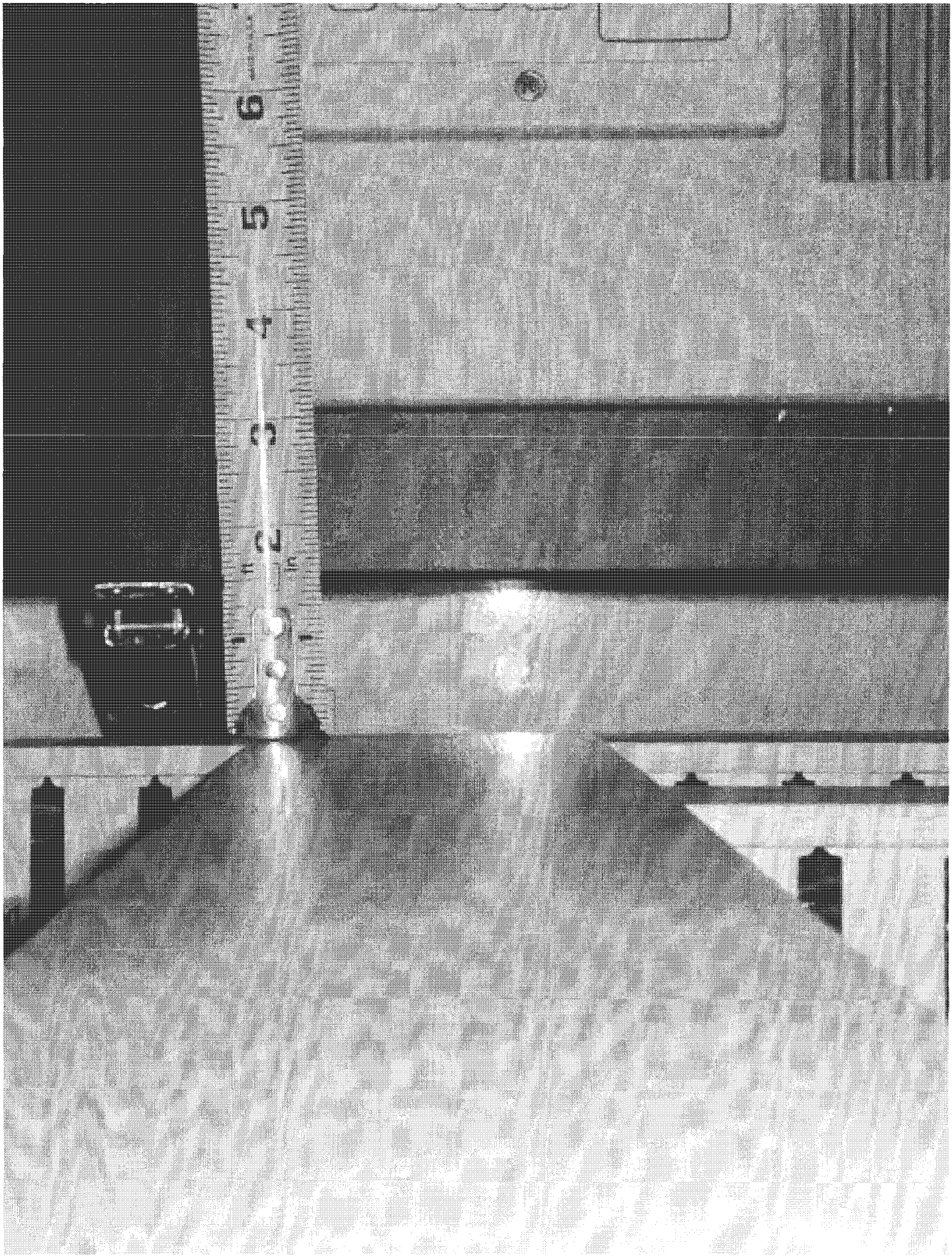

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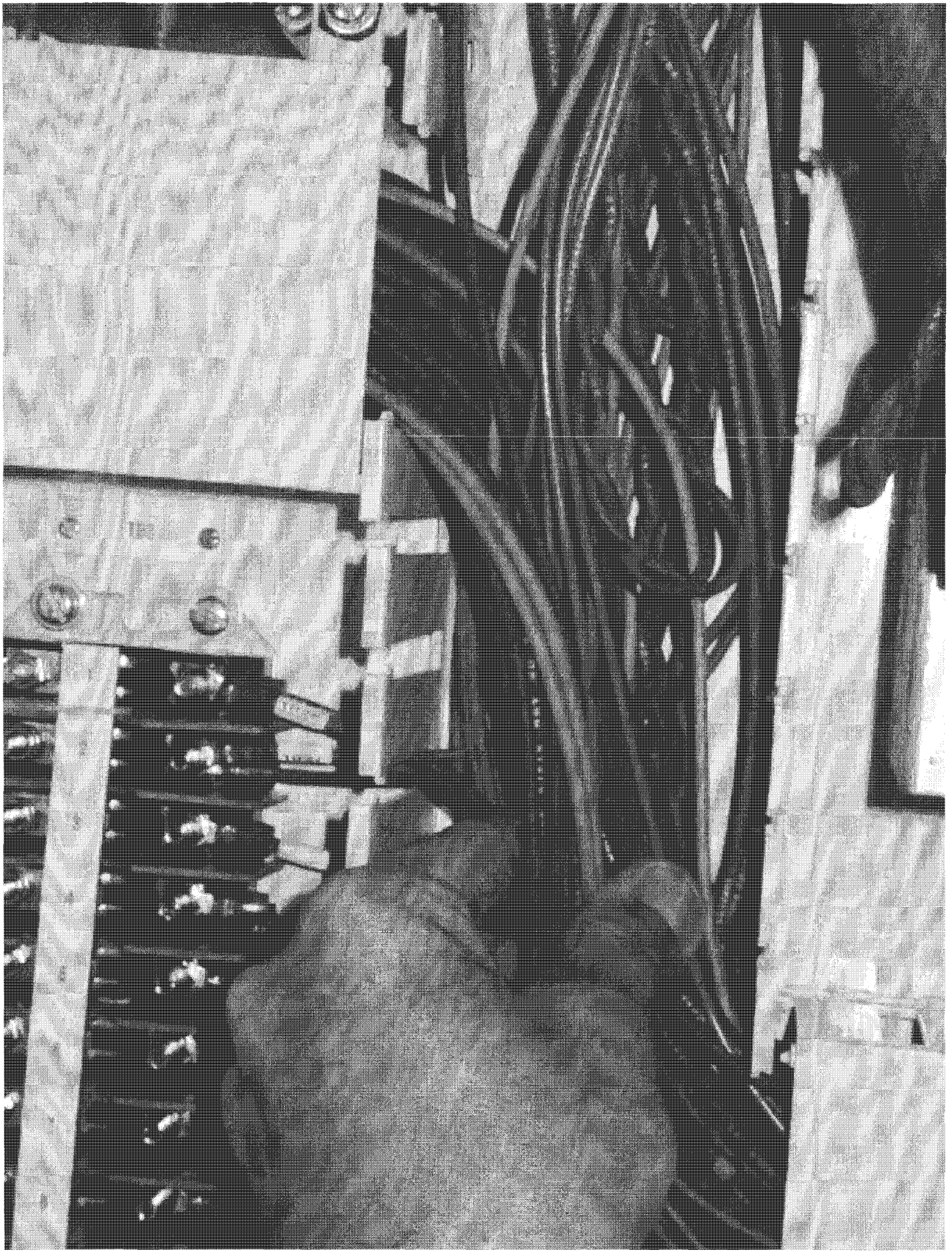

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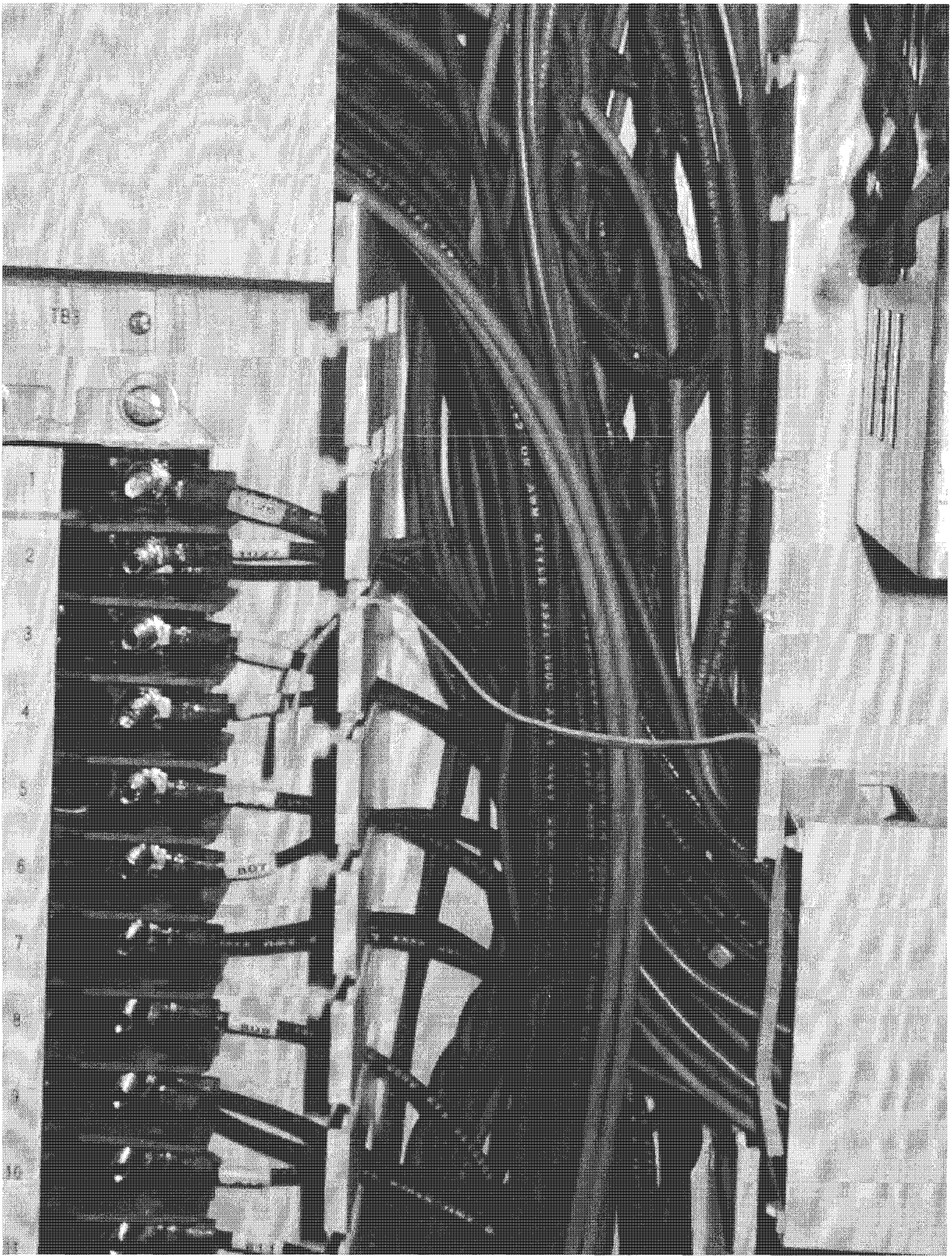

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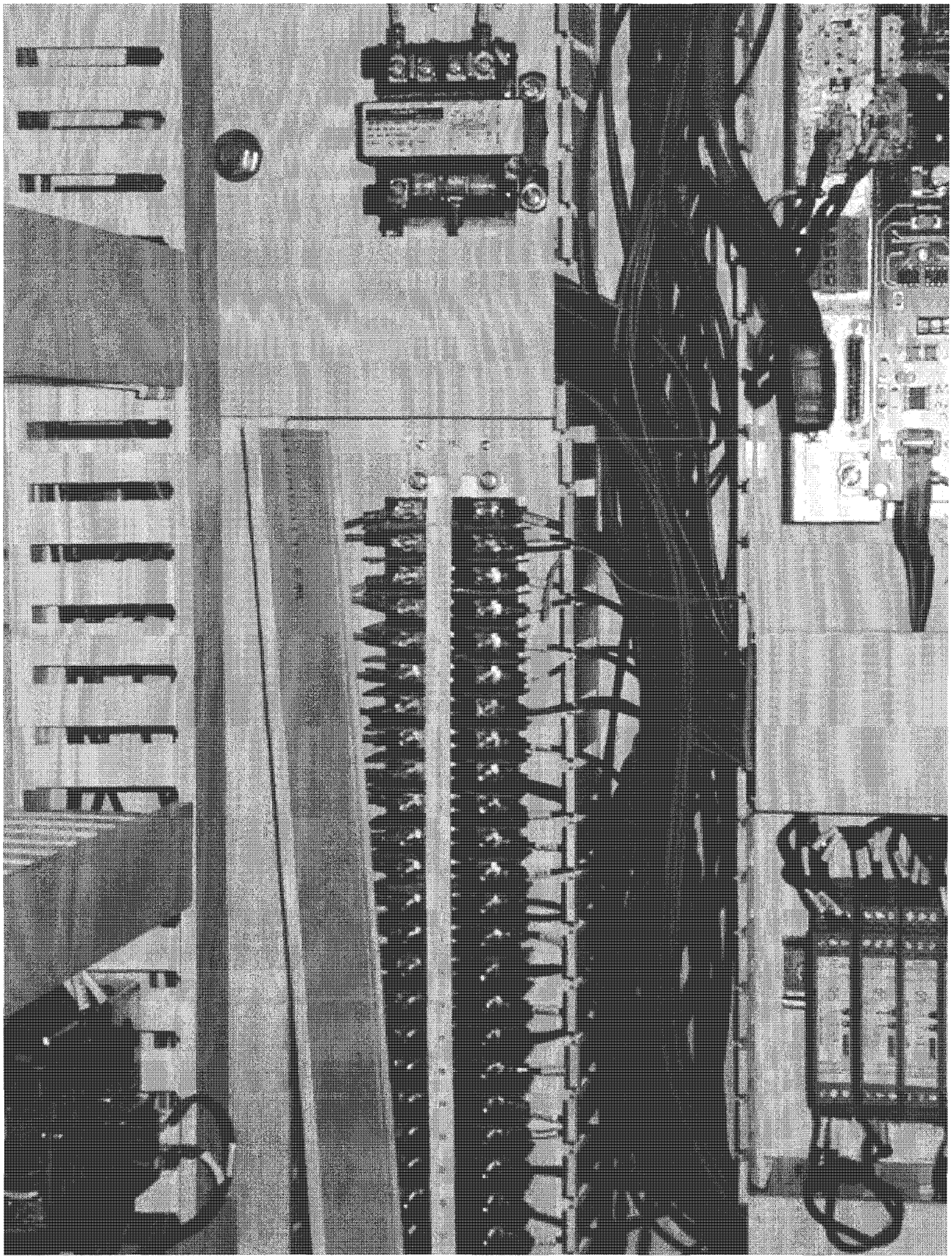

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