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蒸汽发生器二次侧清洁度检查的现场经验

FIELD EXPERIENCE OF CLEANLINESS INSPECTION FOR SECONDARY-SIDE IN PWR STEAM GENERATORS

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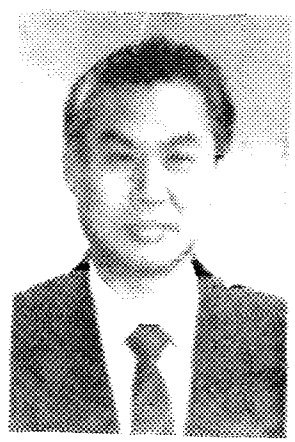

丁训填：核动力运行研究所研究员级高级工程师，核工业在役检查中心主任。1957年毕业于上海交通大学动力机械制造系锅炉制造专业。

Ding Xunshen: Professor of Research Institute of Nuclear Power Operation. Director of Nuclear In-Service Inspection Center. Graduated from Department of Power Mechanical Building, Shanghai Jiaotong University in 1957, majoring in boiler building.

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蒸汽发生器二次侧清洁度检查的现场经验

丁训慎

（核动力运行研究所，武汉）

摘　要

介绍了大亚湾核电站蒸汽发生器二次侧所采用的机械清洗方法与电视检查技术。其目的是防止蒸汽发生器中杂质沉积以及外来物导致传热管的损伤。利用泥渣枪从中间管廊将高压水流射入管束内，由水流机械能粉碎泥渣层，携带着碎渣的水流经外环廊吸出。清洗前的电视检查包括外环廊、中间管廊及其邻近区的清洁度检查和外来物的取出；清洗后的电视检查，包括外环廊、中间管廊及其邻近区、管间的清洁度检查和外来物的取出。电视检查后，需由反映检查过程的录像带来验证和确认检查过程的质量状况。不允许存在漏检、图像不清晰和遗留下能取出的外来物等情况发生。电视检查不仅要提供管板上表面的清洁度状况，而且还必须根据合格标准得出清洁度结论。因此，制订适用于运行后各阶段的清洁度合格标准是重要的。现场实践指出，清洗后，尽管在泥渣堆积区内仍残留有硬渣，并且局部区域的残留高度已超过 5 mm，但整个管板上残留泥渣较少，只要在换料期间对蒸汽发生器进行清洗，可以延缓残留高度的增长速率。

Field Experience of Cleanliness Inspection for Secondary-side in PWR Steam Generators

DING Xunshen
(Research Institute of Nuclear Power Operation, Wuhan)

ABSTRACT

The mechanical cleaning and TV inspection technology for secondary-side in steam generators of Daya Bay Nuclear Power Plant has been used for preventing the heat transfer tubes from damage caused by residues in steam generator and foreign objects. A lancing has been used for steam generators. The high-pressure jet sent from the central lane to the inside of the bundle has two objectives: (a) the mechanical energy in the jet breaks up the deposit, and (b) the particles are then carried to the periphery of the generator, where they are collected by a water circulation system. The TV inspection consists of the inspection before lancing and after lancing. The former includes the inspection of outer tube lane and central tube lane, and the extraction of foreign objects; the latter includes the inspection of intertube area, outer tube lane and central tube lane, and the extraction of foreign objects. Videocassette are visualized by a specialist who is qualified to realize a map representative of the cleanliness state of the tubesheet, and to judge if it is or not acceptable. The TV inspection obtained a cleanliness conclusion according to acceptance criteria. So, it is important to work out cleanliness acceptance criteria suit for every operation stages. The site practices shown that after lancing, although hard deposit existed and height of hard deposit in some local place exceeded 5 mm, but the sludge remaining on tubesheet was less. If we can conduct priodic lancing to steam generator, the increase rate of hard deposit will be small.

INTRODUCTION

In SG of PWR NPP, while earlier problems with sludge deposition, such as tube wastage or denting, have been alleviated, new problems continue to be found. Deposits on tube surfaces and in support plate crevices can concentrate soluble chemical species, resulting in intergranular attack and stress corrosion cracking (IGA/SCC).

In 1989, on the 1, 300 MW PWR NPP of France, the corrosion and leak continually took place on tube secondary of SG [1]. It was found that the deposit material on the tube-sheet most were the metal particle reminded in SG before operation. In the operation period of NPP, after oxidation, the metal particle volume in deposit material began to expand, and it pressed the tube to cause the denting. The oxidized metal deposited layer was high hard and strong corrosive, and it was very hard to be removed. This problem was quite hard to be overcome for secondary cleanliness of SG.

Robotics systems for inspection and repairs in the primary channel head, such as eddy current testing, tube plugging and sleeving, are well developed. These primary side robotic systems are useful for analysing and characterising tube degradation —— for tube plugging decisions for example —— but provide limited information on secondary tube surface conditions [2]. Extremely complicated and limited secondary side access has made robotic system development difficult. Steam generator hand hole sizes is approximately 150 mm, the blow down lane width is 150 mm, but this is often restricted by flow distribution baffles or blocking devices. Upper bundle access is further limited by the size of the flow slots or holes in the support plates. Typical flow slot size is 70 mm by 380 mm. In addition, intertube access is through gaps of less than 10 mm. Because a large number of corrosion cracking tubes has been found on secondary side, so it is paid attention to clean and inspect to secondary side.

1 MECHANICAL CLEANING OF SG SECONDARY SIDE [3]

1.1 Cleaning system and cleaning equipment

At Daya Bay Nuclear Power Plant, The mechanical cleaning of steam generator secondary side employs France SRA Company's mechanical cleaning system. The system is shown in Fig. 1. It consists of eight units, pipes and cables link up the units.

The suction unit is made up of two venture type vacuum pumps and two diaphragm pumps.

The filtration unit is composed of prefilter (23 filter elements 20 μm core filters) and main filter (18 filter elements 8 μm core filters). It is determined by the reading of drop pressure meter that the replacement of core filter, while the reading is higher than 0.25 MPa, the core filter will be replaced.

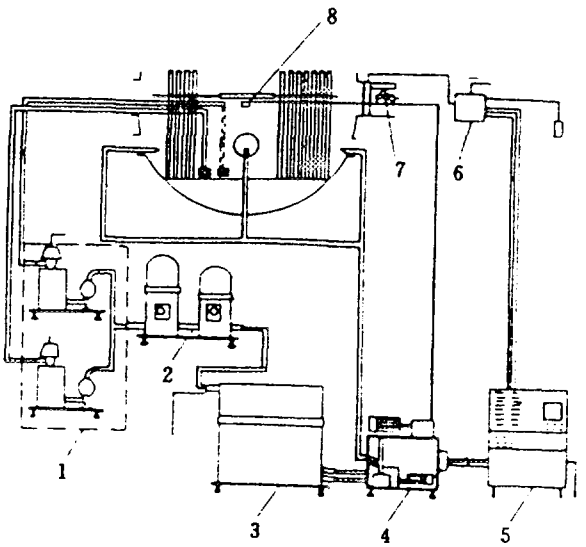

Fig. 1 Mechanical cleaning system of SRA, France

1——Suction unit; 2——Filtraing unit;
3——Storage tank; 4——Pump unit;
5——Control console; 6——Electropneumatic box;
7——Actuator; 8——Sludge lance.

The storage Tank can store 2 m^3 remove salted water, the water level and temperature is controlled by control console.

The pump unit consists of booting pump, high pressure pump, medium pressure pump and the pressure control circuit of high pressure pump exit, the booting pump supplies enough water to the high pressure pump to prevent any cavitation problems. The high pressure pump is piston pump, and the exit parameters: pressure is 35 MPa, flow rate is 5 m^3/h. The exit pressure of sludge lance is restricted by the safety valve, and the pressure is 20 MPa, the flow rate is 5 m^3/h. The exit parameter of medium pressure pump: the pressure is 1.5 MPa, the flow rate is 10 m^3/h.

The control console is made up of the pump unit switch, the work state display panel, the malfunction display panel, the actuator control and the monitor. The pump unit switch executes the start and stop of pumps. The work state display panel can show the state of actuator, the level and the temperature of water tank. And the malfunction display can show the malfunctions of the cable joining, the level and temperature, the pressurized air pressure, the pump's currents and the filtrator's plugging, etc.

The electropneumatic box controlled by the electric signal from control console, supply the electricity and air of actuator. In addition, it connects with the manual operating box of actuator and achieve the control to actuator in short distance.

The actuator control that the sludge lance moves backward and forward, swings left-right, and adjusts the original position of the sludge lance. The actuator divides two types: hand-hole actuator and eye-hole actuator. Its working condition is displayed by monitor.

The sludge lance have two kinds, one is inserted into steam generator from hand-hole (see Fig. 2), it is fixed at flow distribution baffle, and the other is inserted into SG from eyehole, it is fixed at eye-hole flange.

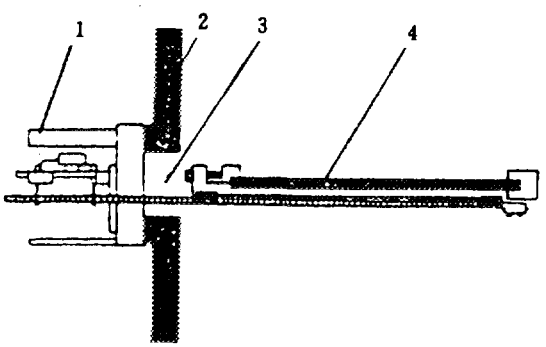

Fig. 2 Hand-hole sludge lane and installation position

1——Sludge lance; 2——Shell;
3——Handhole; 4——Flow distribution baffle.

1.2 Cleaning principle and procedure

The sludge in inter-tube is loosed by the high pressure jet (8～20 MPa) from the sludge lance and is sent to outer circular lane, and the loosed sludge is sent to the suction port by the medium pressure water, then it inhale into the venturi vacuum apparatus, and then it is sent to filtrator by diaphragm pump, in here, the sludge is captured by high property filter elements. The water flows back into storage tank and is used. On venturi vacuum apparatus, there is glass viewing window, through the window, the inner water cleanliness can be observed, and the cleanliness situation on the surface of the tubesheet can be judged.

According to the state of steam generator, the cleaning procedure divides into after hydrostatic testing, after hot functional testing and after major transients testing. There are introduced as follows.

(1) After hydrostatic testing, the cleaning will spend almost 20 hours, the procedure is:

- Main lancing, 8 MPa;
- Last lancing, 1.5 MPa.

(2) After hot functional testing, the cleaning will spend almost 40 hours, the procedure is:

- Pre-lancing, 8 MPa;
- Main lancing, 20 MPa;
- Last lancing, 8 MPa;
- Lancing with medium pressure water, 1.5 MPa.

(3) After major transients testing, the cleaning will spend almost 50 hours, the produre is same as the after hot functional testing, the different is to lance the hot side of center tube bundle using 20 MPa before main lancing.

After the hot functional testing and the major transients testing, it must be done to analyze the sludge sampling before main lancing, if the weight of the metal particles between 0.5 mm and 1 mm in sampling is greater than a certain percent of the sampling weight, the main lancing pressure is not attain to 20 MPa, in case the tube are damaged by the metal particles.

The lancing water must be sampled and pledged its quality, after end of lancing with 1.5 MPa medium pressure water. The chemical analysis should be done to water sampling; the contents of Cl, F, Na, Ca, Mg and sulphate are decided by the permitting sludge hide-out standard on the tube-sheet. The ion action conductivity of lancing water should be measured, and the qualified standard is 5 μs/cm.

2 CLEANLINESS TV INSPECTION OF SG SECONDARY SIDE [4]

2.1 TV inspection equipment

VP3 video processor is used for cleanliness inspection of SG secondary side in Daya Bay Nuclear Power Plant. It's a set of special device to observe small-diameter tubes in interior and on narrow way. Its functions include monitoring and controling, video recording, and picture explaining. It suits for inspecting the regions without outer light supply because it has light source. Since the probe is CCD (Charge-coupled Device), it has good image and high resolution. Adjust cleanliness and brightness to optimum situation via the keyboard. Words can also be added to explain the picture. The probe can be curved 90 degrees in four directions. This make it possible to adjust the viewing directions. With suitable probe and grab tools, it can removal of foreign objects. The above advantages make it fit to inspect cleanliness and for removal of foreign objects.

The main equipment comprise:

(1) VP3 video processor

(2) ϕ12.7×6100 mm probe (for outer and central lane)

(3) ϕ6.1×10600 mm probe (for intertube)

(4) 12.7 cm TV

(5) 33 cm TV and 30 m cable

(6) VP3 keyboard and 30 m cable

(7) multisystem video tape recorder

(8) freeze frame video image recorder

(9) guiding and pushing device

(10) communication system

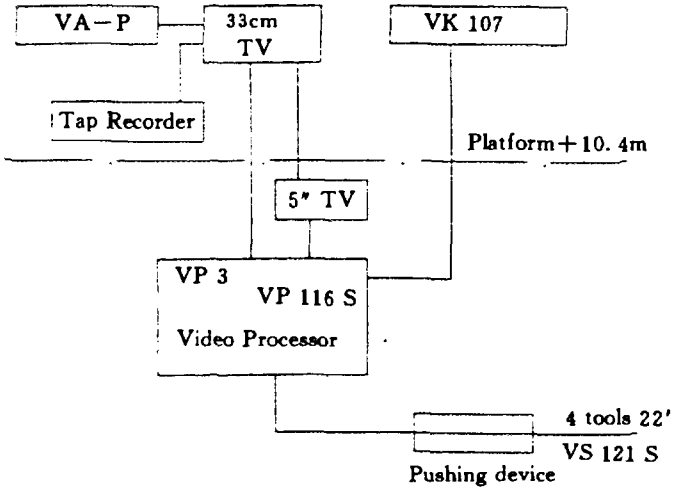

Fig. 3 Connection and distribution of VP3 ITV device

One vacuum cleaner and four grab tools are used, too.

2.2 The guiding and pushing device of video probe

Outer tube lane: Put in ϕ12.7 mm probe, fiber cable, and pushing device from 180 degree (or 0 degree) handhole, push it slowly to the other side, record video and inspect when it returns. Inspect hot side and cold side respectively.

Central tube lane inspection: Put ϕ30 mm duct into the inspected region across upper half circle of blocking device, then put in ϕ12.7 mm probe and fiber cable through the duct, record video and inspect when it returns.

Intertube area inspection: Put ϕ10 mm duct and pushing device in outer tube lane from handhole, and ϕ6.1 mm probe and fiber cable into intertube from duct.

2.3 TV inspection before lancing

ITV before lancing is shown as Fig. 4, comprising outer tube lane, central tube lane, and the adjacent region.

Follow these steps:

(1) Verify the ITV assembly is correctly put together before introducing the probe into handhole.

(2) Open the handholds, eyeholes and take out plugs on tube wrapper.

(3) Introduce probe and pushing device through the handhole (180 degree or

0 degree) into SG, identify all tools introduced into SG.

(4) Inspect outer tube lane and adjacent area, adjacent area is meant the area extended 2～3 tubes to the tube bundle.

(5) Record and photograph the position, diameter, length, width, shape, color, nature (if possible) of all foreign bodies on video cassettes carefully.

(6) Remove foreign bodies using tools if it is necessary and possible.

(7) Review of video tape and mapping.

(8) Demobilization, remove probe, pushing device and others from handholds. Disconnect video assembly. Identify all tools removed from SG and verify that no any part is missing in SG.

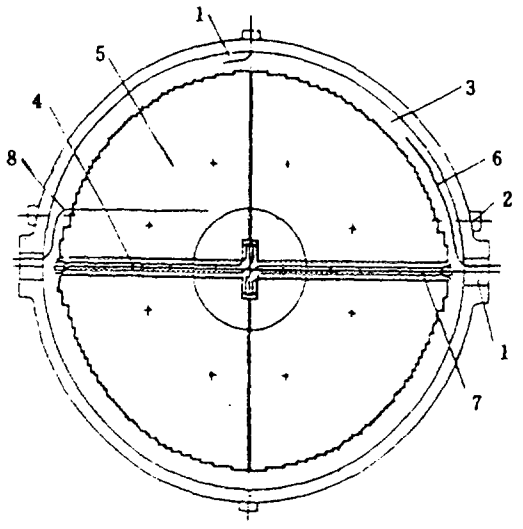

Fig. 4 Inspection position and tools

1——Handhole; 2——Eyehole;
3——Outer tube lane; 4——Central tube lane;
5——Intertube; 6——Tools for outer tube. lane inspection;
7——Tools for central tube lane inspection;
8——Tools for intertube inspection;
9——Monitoring probe.

(9) Introduce the duct and probe through the handholds (180 degree or 0 degree) into the central tube lane, identify all tools introduced into SG.

(10) Inspect central tube lane and adjacent area. Adjacent area is meant the area extended 2～3 tubes to the central tube lane.

(11) Record and photograph the position, diameter, length, width, shape, color, nature (if possible) of all foreign bodies on video cassettes carefully.

(12) Remove foreign bodies using tools if it is necessary and possible.

(13) Review of video tape and mapping.

(14) Demobilization, the same as (8).

2.4 TV inspection after lancing

ITV after lancing is shown as Fig. 4. The inspection includes outer tube lane, central tube lane and their adjacent area, intertube area.

Follow these steps:

(1) Check tubesheet for dryness. Any water is not permissible.

(2) Inspect outer tube lane, central tube lane and their adjacent area, the same as 2.3.

(3) Verify the ITV assembly is correctly put together before introducing the probe and guide tube into handhole.

(4) Identify all tools introduced into SG.

(5) Insert the probe and its pushing device into handhole (180 degree or 0 degree) positioning it to face the intertube to be inspected. One in three lines has to be inspected.

(6) Inspect intertubes step by step. Pay attention to marks of tube positioning.

(7) Record and photograph the position, diameter, length, width, shape, color, nature (if possible) of all foreign objects on video cassettes carefully.

(8) Remove foreign objects if it is possible.

(9) Review of video tape and mapping.

(10) Demobilization, remove probe, pushing device and others from handholds. Disconnect video assembly. Identify all tools removed from SG and verify that no any part is missing in SG.

2.5 Removal foreign objects

Usually we define foreign objects as any objects that geometry is larger than 5 mm (i. e. about half distance between two tubes). These scattered foreign objects on tubesheet are manufactured and installed residuums (that is to say grinding and welding residue, metal particles, welding rod etc.), loose parts, bodies from system, sludge deposits etc. One vacuum cleaner and four special tools are used to do it. The foreign objects in the outer tube lane and central tube lane must be removed. Cleaner is supplied with compressed air. Four special tools include alligator forceps, snare, retrival magnet, four-prongretrival. Foreign objects removal is carried out under video monitoring. Place the grappling tool or vacuum cleaner as close as possible to the foreign object to be removed. Open tool jaws and grapple the object once in touch with the object, remove it (use vaccum cleaner to remove it, if it is possible). All removed foreign objects will be localized and photographed. Foreign objects between tubes include two kinds: the loose objects and wedged objects (see Fig. 5 and Fig. 6). The loose objects can move freely between the tubes. When cleaning with high-pressure jet, high-speed water will carry them to somewhere, or they may damage heat transfer tubes. The wedged objects are mainly graping within two or more tubes. They may also damage the tubes.

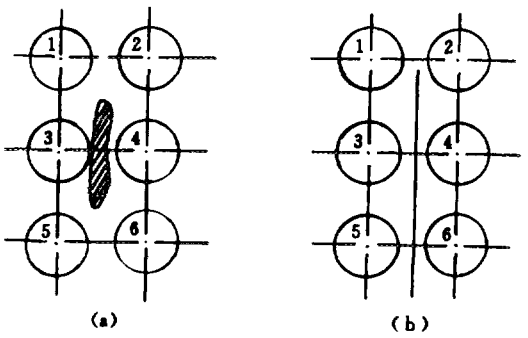

Fig. 5 Loose foreign objects
(a) welding sludge;
(b) metal wire.

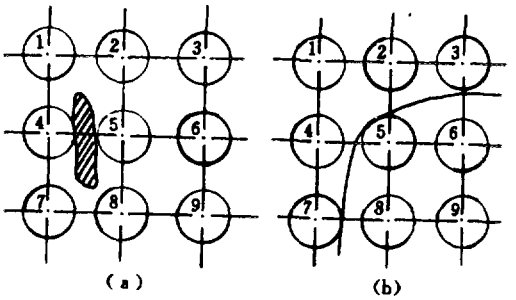

Fig. 6 Wedged foreign objects
(a) welding sludge;
(b) metal wire.

In the event that foreign bodies are found, the following position should be adopted:

● Remove them, if possible (depending on accessibility and adherence).

● If these foreign bodies adhere, this condition shall be accepted for the time being.

A detailed description of these foreign bodies (diameter, length, width, nature if possible, shape, color, etc.) should be prepared and a report justifying their harmless nature (if this is the case) will be issued.

After an unsuccessful attempt of removal, a loose part may be left in place. However, at the next shutdown, ensure it is no longer in its original position and retrieve it from its new location.

After an attempt of removing a wedged object, the following should be carried out:

● If the attempt was successful, the tubes that were in contact with the object, together with adjacent tubes, should be eddy current tested.

● If it cannot be removed, it may be left in place and its presence shall be checked after scheduled shut down, and together contact tubes, should be eddy current tested.

2.6 Analyzing, judging and mapping of the video casettes

Videocassette are visualised by a specialist who is qualified to realise a map representative of the cleanliness state of the tubesheet, and to judge if it is or not acceptable.

Realise map on the following way:

(1) Visualisation of all the videocassette, to have a general idea of the tubesheet cleanliness, hot and cold side.

(2) Visualisation of the whole line to be mapped, before counting the tubes, so as to have a global idea about its cleanliness state.

(3) The tubes will be counted from 10 to 10.

(4) For the mapping, particular poins such as foreign object, have to be assigned exactly to the corresponding tube.

(5) Different symbols represent an averge of the deposit present for each group of 10 tubes. The symbol chosen shows the sort of deposit present (granular or fine dust, granular or powdery deposit) and its frequency indicates the amount of deposit encountered.

2.7 Acceptance criteria

The TV inspection not only provides cleanliness state on tube sheet but also obtain a cleanliness conclusion according to acceptance criteria. So, it is important to work out cleanliness acceptance criteria suit for every operation stages. After hot functional testing and major transients testing, the relevant criteria are:

(1) The foreign objects in the other tube lane and central tube lane must be removed. The foreign objects in the intertube area are removed as possible. If it cannot be removed, a detailed descripition of these foreign objects should be prepared and judging damage and affectness.

(2) On the whole tubesheet, a sludge thickness of 1 mm is acceptable.

(3) Thicknesses of 2 to 5 mm are also acceptable but only in the case of small areas of sludge (less than 20% of the total surface).

3 FIELD EXPERIENCE OF TV INSPECTION [5~7]

According to " Televisual Inspection of Cleanliness in Secondary Side of Steam Generator" periodic inspection procedure, its relative document ——"Quality Safety Plan", and "reinspection of foreign object remain in 2RCP 001GV discovered in last ITV inspection", RINPO ITV team inspect the cleanliness in secondary side steam generator of GNPS 2RCP secondary ISI.

The work include: before lancing inspection, after lancing inspection, the removing of foreign objects and the reinspection of foreign objects remain in 2RCP 001GV discovered in last inspection (Line 33~34 Column 23~24, Line 24~25 Column 36~37).

The whole process and main results are as follows:

3.1 TV inspection of GNPS 2RCP 001GV

Before lancing inspection

Residual water on tube sheet was discovered in outer tube lane and central lane. It should be pointed that residual water affect the inspection quality.

Metal foreign objects were not discocered. Fine dust was (<0.5 mm) discovered in some area. Outer tube lane was clean. Fine dust was discovered in the near area of cental tube lane.

After lancing inspection (Fig. 7, 8)

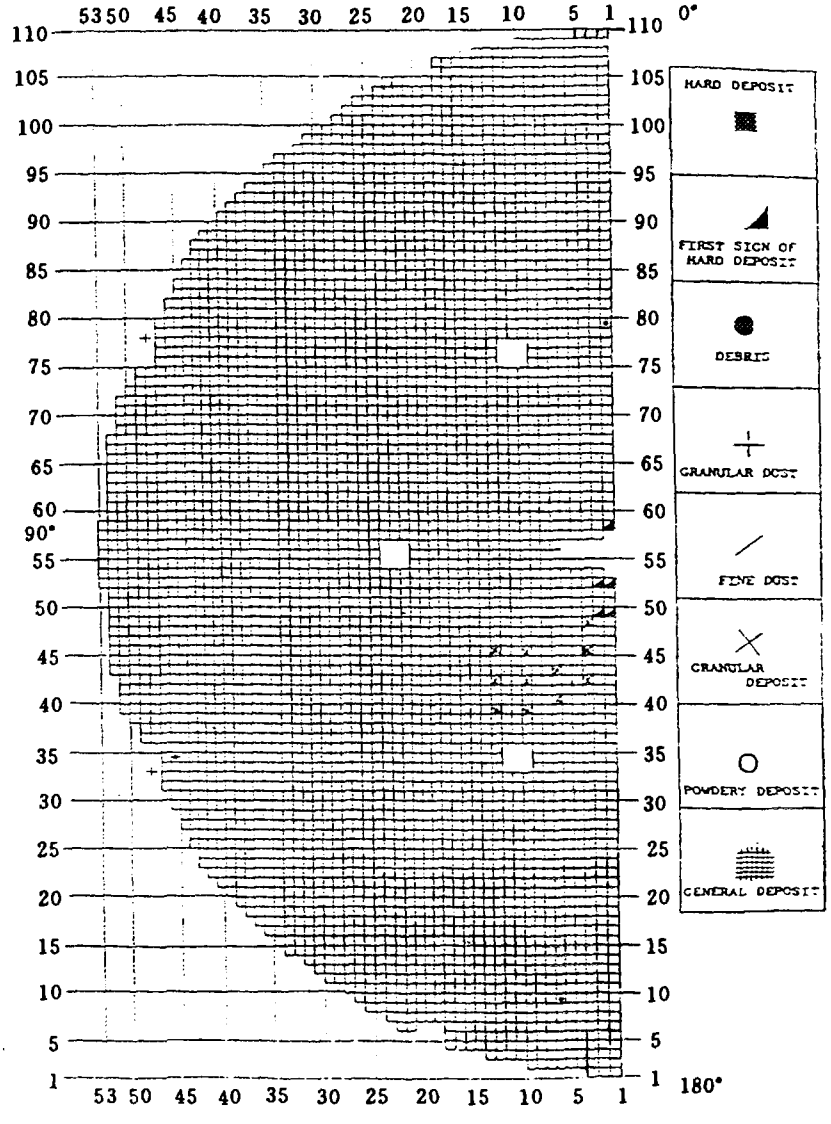

Fig. 7

Three foreign objects were discovered in outer tube lane. They were removed by grapphing tool. They are: metal wire (Line 33～34, Column 13～14 hot side), welding slag (Line 20～21, Column 6～7 hot side) and metal scrap in outer lane (cold side, Line 13～14, Column 2～3).

A foreign object was discovered near the 180 degree hand hole in central tube

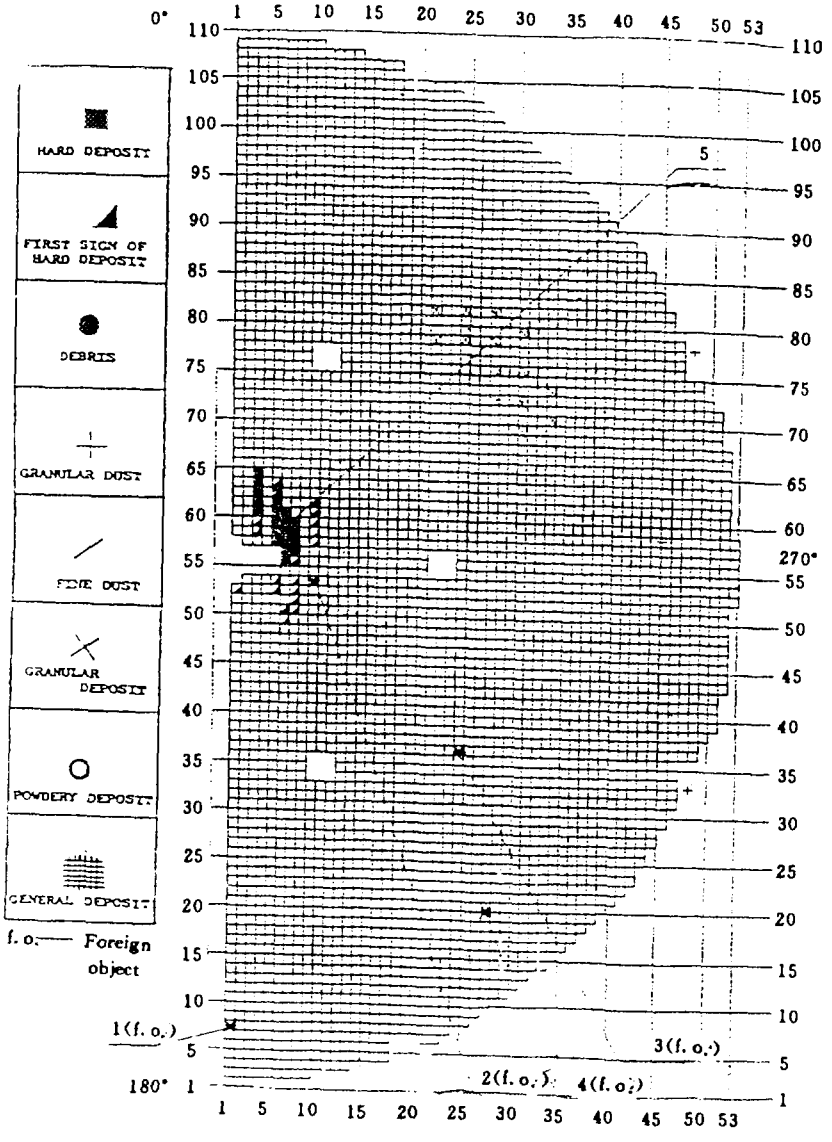

Fig. 8

lane. Hard deposit was discovered in hot side of central tube lane.

The hard deposit and first sign of hard deposit were discovered in central part of the intertube area and each side of central tube lane. According to the distribution of dust deposit, the conclusion is: They exist in each side of central tube lane, they exist in hot side more than cold side. In hot side the highest dust deposit should appear at Line 6～8, Column 57～62.

A few dust deposit remain in inter-tube area. The lancing is efficient. It conform to the cleanliness stantard. Some hard deposit and first sign of hard deposit can not be removed by lancing. Some different kind of foreign objects and dust remain in the tube sheet.

According to the procedure, four foreign objects were discovered ($\geqslant$5 mm) in

hot side, none in cold side. One is metal wire and others are weld slag. The weld slag (Line 1～2, Column 7～8) is removed. Other remain in the SG due to no suitable grapping tool. We consider the metal wire (Line 9～10, Column 53) can not hurt the tube because it is very light. The weld slag may hit its nearest tube in the S. G. operation.

The whole process include the reinspection of two metal foreign objects remained in the S. G. discovered during last periodic inspection. Their positions are Line 33～34, Column 23～24 cold side (metal scape), Line 24～25, Column 36 ～37 cold side (weld slag). We inspected two positions and its near area. None foreign objects was discovered. But one removed foreign object is very similar to the metal scrap in the Line 33～34, Column 23～24 of remain.

3. 2 TV inspection of GNPS 2RCP 002GV

Before lancing inspection

In the course of inspecting outer tube lane, cental tube lane and the adjacent area, we found there is residual water on tube sheet, as high as 4～5 mm. According to the path of pushing device, we considered that there are sludge deposits on the tube sheet under the water. Meanwhile, we found a dark foreign object lie in hot side L27～28, C9. It was identified a nonmetalic floating object which can be moved during lancing.

In central tube lane inspection, most area was clear except some place. No metalic foreign objects were found.

After lancing inspection (Fig. 9, 10)

Outer tube lane inspection

The outer tube lane and the adjacent area. Both cold side and hot side were clean, but there were obvious sludge deposits near the tube, especially on the area of Column 1～20, Column 90～110. The sludge deposits were also found on the tube sheet under to 90 degree and 270 degree eyeholes, and the sludge deposits were removed with vacuum cleaner.

There were 2 foreign objects on the hot side, Line 52～53, Column 64 and Line 20～30, Column 10～11, they are both welding slag.

On the area of cold side Line 34～35, Column 14～15 found a metal scrap, it is about 45 mm long and 10 mm wide. The three foreign objects were removed with vacuum cleaner and grappling tools.

Central tube lane inspection

The central tube lane and the adjacent area clean except some sludge deposits

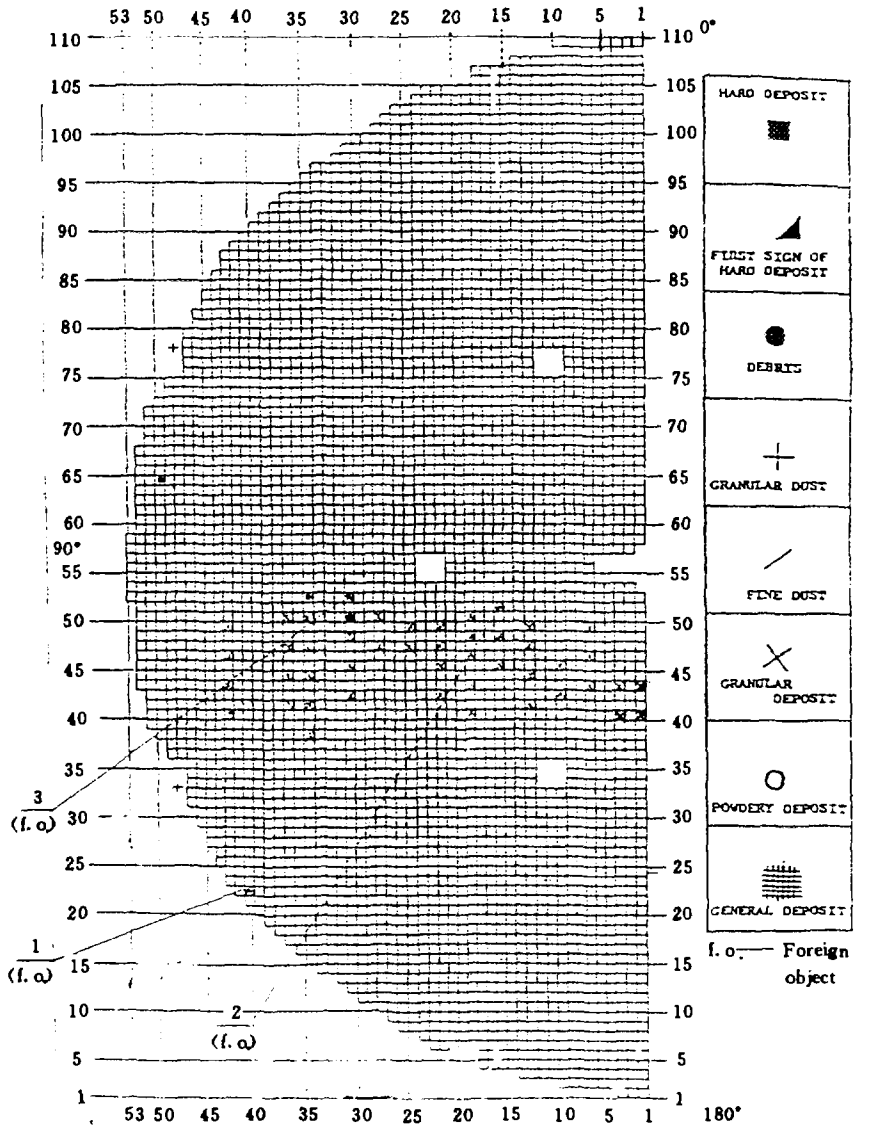

Fig. 9

on some place and welding rod about 125 mm, ϕ2～3 mm on the hot side Line 1～2, Column 59～64. It was so long that took 70 minutes to remove it out with grappling tools.

Intertube area inspection

The hard deposit and first sign of hard deposit show that sludge deposits mainly distributed above the center on the hot side. It was estimated that the height of the most deposits left on tubes was over 30～40 mm. Across bridge was very seriously along the column, and the height was above 6 mm and ϕ6.1 mm probe couldn't pass (as Line 6～7, Line 5～6, Line 4～5, Line 3～4). It was mainly relative with the operation time and the limitation of the machanical lancing.

There were 3 foreign objects on cold side and 2 on hot side. Two of them was

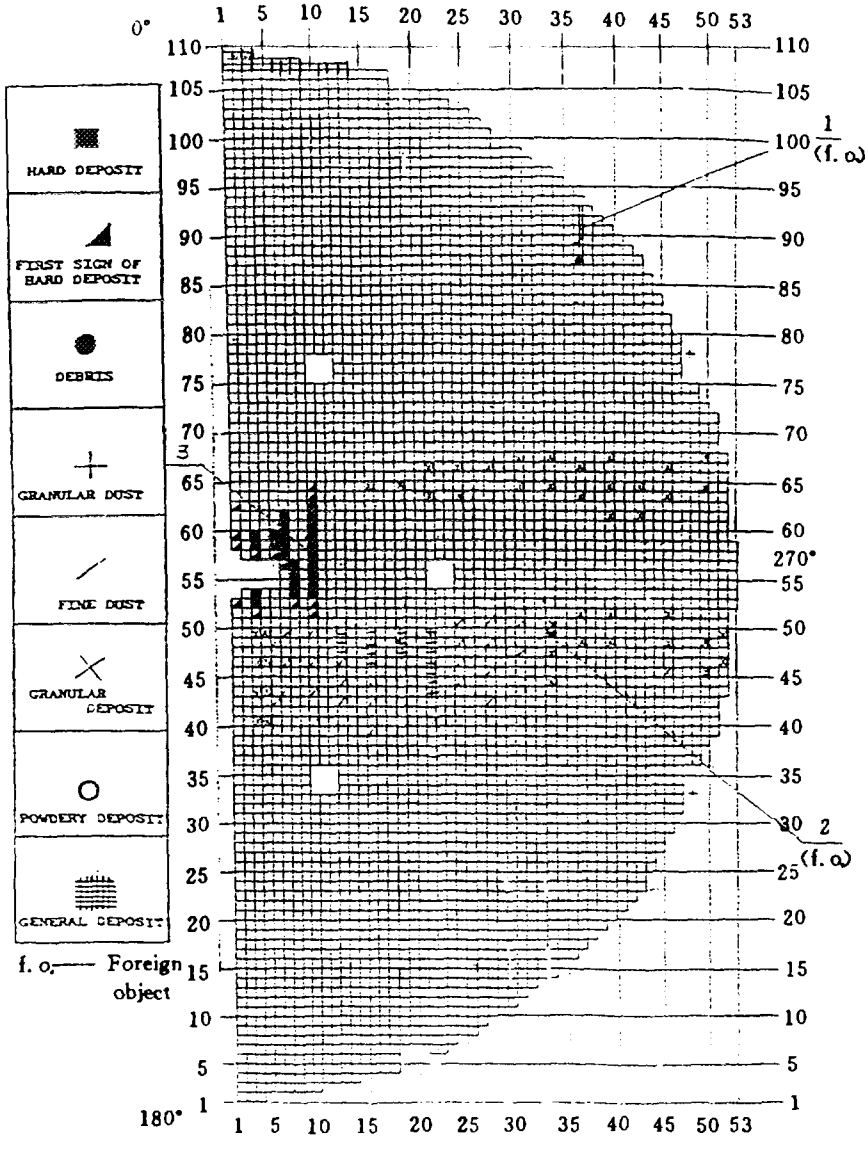

Fig. 10

removed. The one on cold side Line 40～41, Column 22～23 is an iron wire, 35 mm long. The other on hot side Line 36～37 is a weld wire, 210 mm long. The three foreign objects couldn't removed because of their place and without suitable tool.

Inspectors checked two metal objects discovered during first outage inspection. They are a metal scrap on Line 42～43, Column 58～59 and a welding rod 54 mm long, on Line 30～32, Column 33～34. Now they don't be there. But the one removed from cold side outer tube lane Line 34～35, Column 14～15 is very like the metal scrap on shape, can be considered being the same one.

Video tape judgement of intertube area inspection: The sludge deposit in 002GV is worse (special in hot side). Although the local height of sludge is over 10 mm, to the whole tubesheet cleanliness of 2RCP002GV is still up to standard con-

sidering the limitation of criterion. Three discovered foreign objects have not been taken out. We suggest that to do ET inspection to their adjacent tubes and to check their position in next refuel duration are necessary.

3.3 TV inspection of GNPS 2RCP 003GV

Before lancing inspection

Approximate 2 mm depth of residual water was found in outer tube lane, central tube lane and their adjacent area, but no foreign object was fountd in this area. On some place of outer tube lane and its adjacent (e. g. hot side column 70～43, cold side column 107～50) fine dust existed. Hard deposit can been seen on the adjacent area of hot side central tube lane. Fine dust also can been seen on some local place of central tube lane.

Compared with 2RCP002GV, sludge deplosit in 003GV tube lane was more serious, but the hard deposit in the central of central tube lane was lighter.

After lancing inspection (Fig. 11, 12)

Two foreign objects (both welding slag) were found in outer tube lane. Fine dust existed near 0 degree and 180 degree handholes. This fine dust had been removed by vacuum cleanner.

Fine dust also was found in central tube lane. The deposit mark of hard deposit can be seen on hot side. No foreign object was found.

During one-third intertube inspection, hard deposit and first sign of hard deposit were found on tubes and tube sheet. From these phenomena, we can conclude that sludge deposit area on SG tubesheet lie in hot side center of tube sheet, and the height of deposit may be more than 40 mm. In the direction of column, across bridge was serious, and the width of bridge was so small that the ϕ6. 1 mm probe can not pass.

Sludge agglomerates were also distributed on tubesheet (e. g. hot side Line 24 ～25, Column 78). These sludge aggolmerates being compact and solid in texture may be damage to the tube.

After lancing, sludge like fine dust and granular deposit on 003GV tubesheet was less obviously than 002GV. It was meant that the lancing effect of 003GV was excellent.

Nine foreign objects among which 3 distributed on cold side and 6 on hot side were discovered during one-third intertube inspection. One in cold side and three on hot side were taken out. Two on cold side and three on hot side were still remained an tube sheet because of their inaccessiblity. Among these remainer there were 4

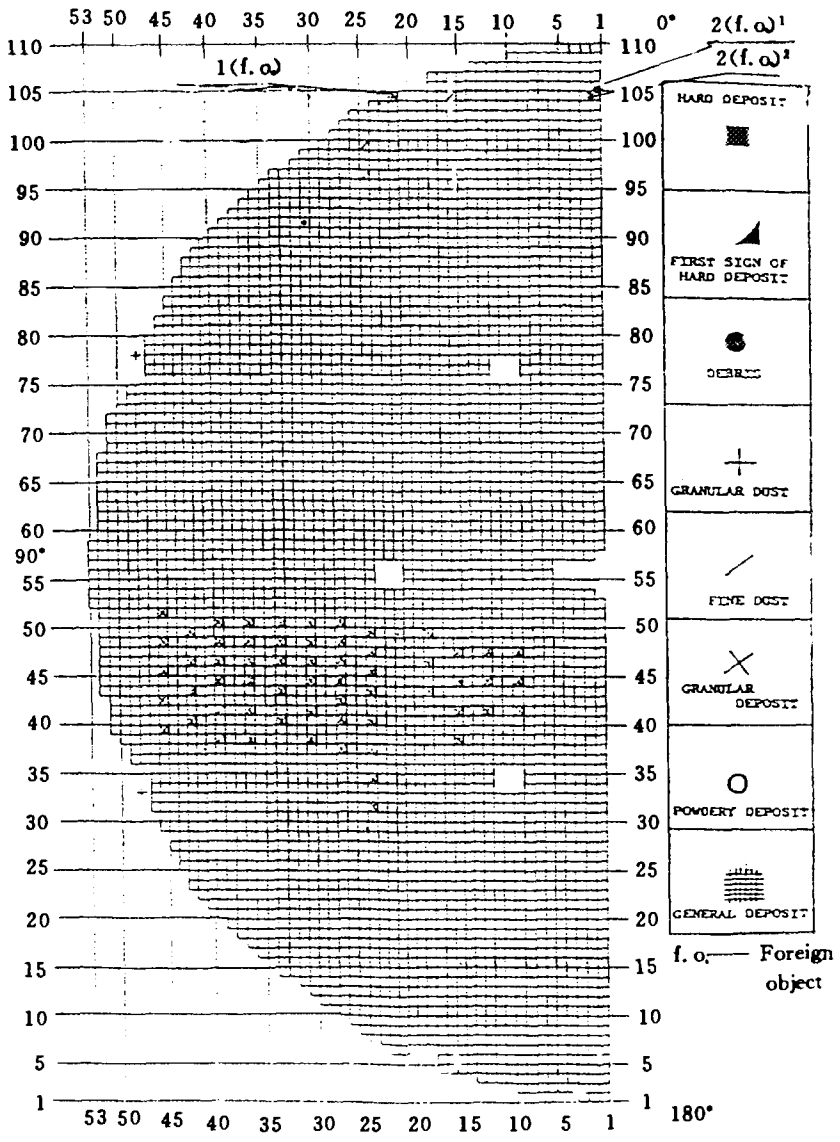

Fig. 11

welding slag and 1 sludge agglomerate. Being hard and sharp, they should be monitored although they are not metallic foreign objects.

Conclusion: Although hard deposit existed and height of hard deposit in some local place exceeded 40 mm, the sludge remaining on tubesheet was less. If we can conduct priodic lancing to steam generator, the increase rate of hard deposit will be small and the life of steam generator can be prolonged. Of couse, it is necessary, to monitor the tubes in sludge area (e. g. Eddy Current Inspection).

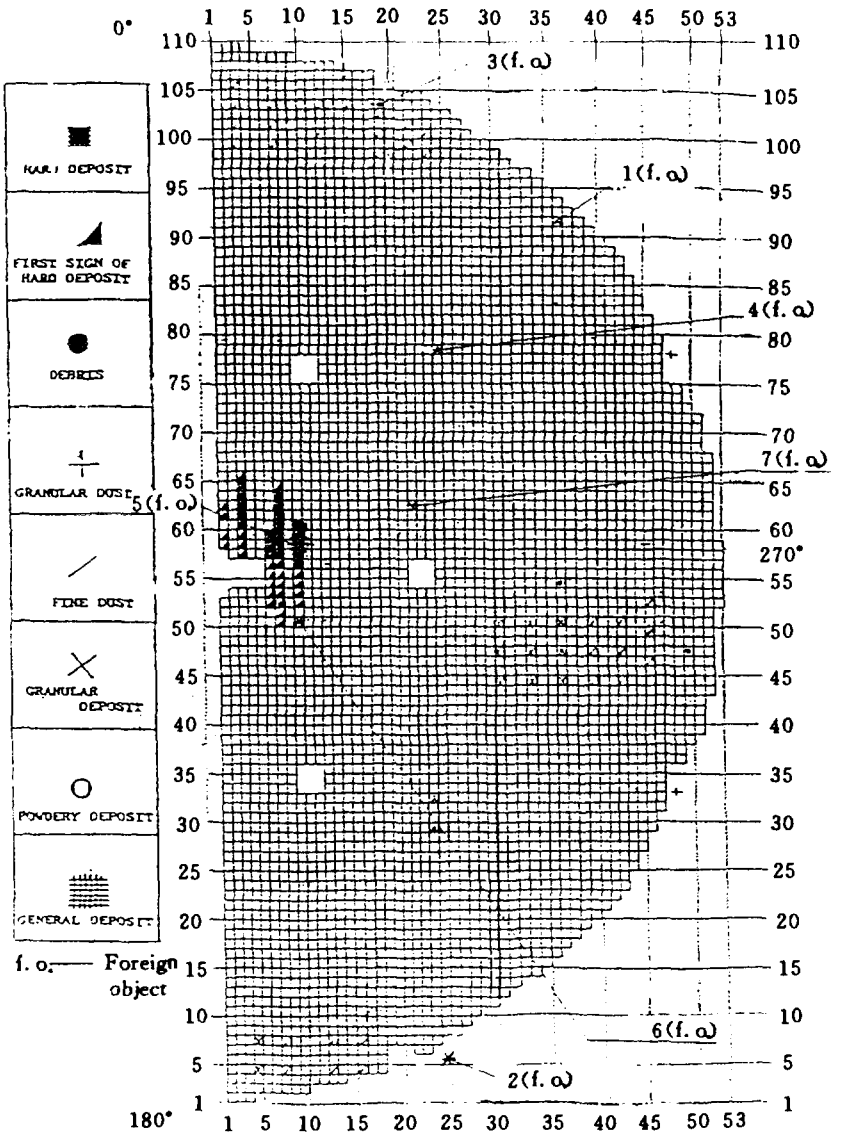

Fig. 12

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