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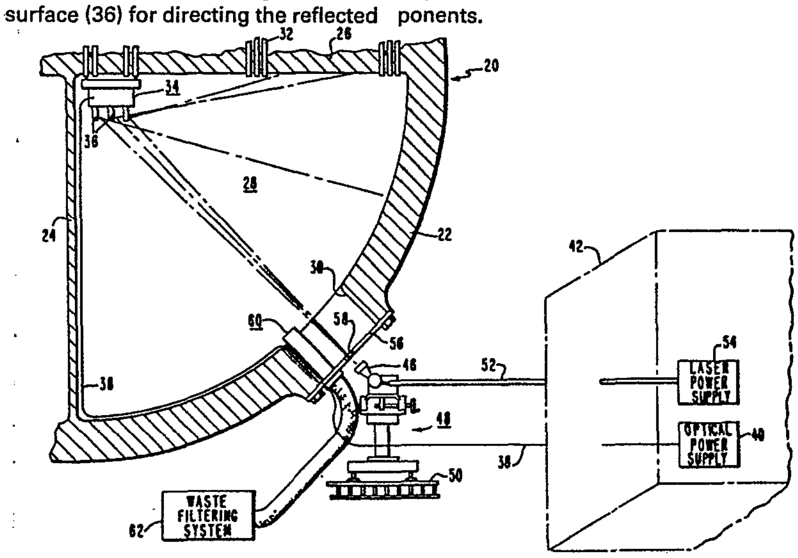
(54) **Laser decontamination method.**

(57) The laser decontamination method comprises directing a laser beam (58) at the surface of the radioactive component to be decontaminated for removing the radioactive oxide layer from the component without damaging the component. The method further comprises reflecting the laser beam from a reflective surface (36) for directing the reflected laser beam to inaccessible areas of the component to be decontaminated. In addition, the method may comprise isolating the area to be decontaminated so that the oxide film that is removed from the component may be collected so as to prevent recontamination or contamination of other components.



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LASER DECONTAMINATION METHOD

This invention relates to decontamination methods and more particularly to methods for decontaminating components of nuclear power plants with the aid of lasers.

During the operation of nuclear power plants and similar apparatus, certain components become exposed to radiation and may develop a thin radioactive film on the surface of the component. From time to time, it is necessary to either inspect or repair these components of the nuclear reactor power plant. During the inspection or repair of the components, it is necessary for working personnel to enter the component or to be stationed in close proximity to the component whereby the working personnel may be exposed to radiation emitted from the contaminated component. In some circumstances, the radiation emitted from these components is such that a worker would receive the maximum permissible radiation dose in less than five minutes of working time. Such a situation means that a given worker may spend only a relatively short amount of time working on the inspection or the repair operation of the nuclear component. Having each worker spend a relatively short amount of time in the repair or inspection procedure, necessitates the use of many workers with each worker working a short time, in order to accomplish the desired result. While this may be an acceptable practice for minor inspections or repair procedures, this is not an acceptable practice where there is an extensive inspection or an extensive repair job to be performed. Where the procedure to be performed is a time-consuming procedure, it is likely that an unusally large number of highly trained personnel would be necessary to carry out the task. Such a situation may not only be unacceptable from a financial aspect, but may also be unacceptable from a manpower level aspect. A solution of this problem may be to reduce the radiation field associated with the component to allow the working personnel a longer working time. One approach for reducing the radiation field associated with the nuclear component on which the repair operation is to be performed, is to remove the deposited film of radioactive metal oxides from the exposed surfaces of the nuclear component.

There are several methods known in the art for removing the radioactive oxide layer from the nuclear component so as to reduce the radiation field associated with that component. For example, an abrasive grit may be sprayed against the component to abrade the oxide film from the component thereby lowering the radiation field associated with the component. In addition, chemical processes have been attempted to dissolve the oxide film from the component to thereby remove the oxide film and associated radiation field from the component.

In addition to the methods that have been previously attempted for reducing radiation fields associated with nuclear components, it is known in the prior art to use laser radiation and radiation from pulsed flash lamps to remove various kinds of surface films from objects such as artworks and structures. This type of laser radiation may employ intensities which have the ability to kill mildew on rare old books, to remove paint from metal surfaces, to chip away limestone deposits from Indian cliff paintings or to convert rust to magnetite on steel structures. However, none of these procedures have been developed for use in removing radioactive oxide films from nuclear components in a manner to prevent damage to the nuclear component and in a manner to prevent redeposition of higher levels of radioactive oxides on the nuclear component.

It is therefore the principal object of the present invention to provide a decontamination method that reduces the radiation field adjacent to components of nuclear reactor power plants without damaging the component or creating a situation in which the rate of deposition of radioactive oxide on the component is accelerated when the component is returned to service.

With this object in view, the present invention resides in a. method for decontaminating radioactive nuclear components by removing a thin oxide layer of radioactively contaminated metal from the surface of said components thus lowering the radiation level associated with said components characterized in that the surface of said components is scanned by a laser beam of an energy density sufficient to achieve a thermal penetration corresponding to the thickness of said oxide layer and of a width substantially larger than the thickness of said oxide layer.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanied drawing, wherein the single figure is a schematic diagram of the laser apparatus to be employed. The invention, described herein, is a method for laser decontaminating nuclear components so that working personnel may perform operations thereon.

A one-dimensional surface heating model of a laser beam interacting with a surface is generally known in the art. This model assumes that the laser beam is uniform with no transverse variations and that the surface film is approximately uniform. The model also assumes that the surface is planer and normal to the incident laser beam. These conditions are approximately true if:

1. The transverse dimensions of the actual laser beam are much greater than the surface film thickness;

2. The transverse dimensions of the actual laser beam are much greater than the thermal diffusion distance in the material; and

3. The lateral scale size for changes in the surface contour and film thickness is much greater than the average film thickness.

The first condition is satisfied in most situations where the laser beams are 0.1 to 1 cm in diameter and the oxide films of interest are typically less than 10^{-4} cm (approximately 40 microinches). In the case of typical nuclear components, the transverse dimensions of the actual laser beam are much greater than the oxide film thicknesses of the nuclear reactor component which satisfied the first condition. The second condition requires consideration of the thermal diffusivity for the material and the laser pulse length. For typical metals and metal oxides of nuclear reactor components, the thermal diffusivity is approximately 0.2 cm sq. per second. The distance that a thermal wave will advance into such a material during a typical laser pulse length of approximately 1 microsecond is approximately 4.0×10^{-4} cm which easily satisfies the second condition that the transverse dimensions of the actual laser beam be much greater than the thermal diffusion distance into the material. The third condition should be satisfied over most of the area of the nuclear component, because the lateral scale size for changes in the surface contour and oxide thickness is much greater than the average oxide thickness itself. Therefore, it appears that a one-dimensional surface heating model of a laser beam interacting with an oxide covered surface will adequately predict the interaction of a suitable laser on the oxide layer of a nuclear component.

As noted earlier, the oxide films encountered on nuclear components are typically less than approximately 10^{-4} cm. thick. It has been found that to achieve thermal penetration depths comparable to the film thicknesses on these components thereby avoiding extensive thermal damage to the base metal, the laser pulse length should be approximately one microsecond in duration. Both the pulsed TE CO_2 laser and Q-switched YAG laser can be used to satisfy this pulse length criteria.

In addition to determining the penetration depth of a pulse of the laser, it is also important to be able to determine the oxide surface temperatures as a function of the incident laser pulse length so as to be able to ascertain the laser energy densities required. In order to remove oxide films of this nature, high surface temperatures of approximately 2,000-3,000°K are generally required. Since short laser pulses of approximately 1 microsecond are required to limit the thermal penetration depth to avoid base metal damage and in order to achieve surface temperatures of approximately 2,000-3,000°K with a laser pulse length of approximately 1 microsecond, it is generally desirable to have laser energy densities of approximately 1.5 to 3 joules per square cm. Laser energy densities of approximately 1.5 to 3 joules per square cm. are easily produced by pulsed CO_2 and YAG lasers.

From this analysis, it can be seen that lasers are available having the required characteristics to remove radioactive oxide films from nuclear components without damaging the base metal of the component.

Referring to the drawing, a typical nuclear component that may be suitable for radioactive decontamination may be a nuclear steam generator and is referred to generally as 20. Steam generator 20 comprises an outer shell 22 with a divider plate 24 and tubesheet 26 disposed therein as is well known in the art. Outer shell 22, divider plate 24, and tubesheet 26 define a plenum 28 through which the reactor coolant passes. In addition, a manway 30 is provided in outer shell 22 for allowing access to plenum 28 by working personnel. During operation of steam generator 20, a reactor coolant flows through plenum 28 and through tubes 32 which are disposed through tube sheet 26. Since the reactor coolant flowing through steam generator 20 is radioactive, various surfaces of steam generator 20 become deposited with an oxide film that is radioactive. For example, the inner surface of shell 22, divider plate 24 and the lower surface of tube sheet 26 develop an oxide coating thereon that is radioactive. When it is desired to perform maintenance on heat exchanger tubes 32, working personnel may enter plenum 28 through manway 30 to perform maintenance on tubes 32. In order to increase the time in which working personnel may remain in plenum 28 to perform the maintenance, it is desirable to reduce the radiation field in plenum 28. This may be accomplished by removing the oxide film that is deposited on the surfaces of the components of steam generator 22 such as divider plate 24, tubesheet 26 and the inner surface of shell 22 thereby reducing the radiation field emitted therefrom. The invention described herein provides a laser decontamination means for removing the oxide film on the surfaces of steam generator 20 to thereby reduce the radiation field associated with those surfaces.

Still referring to the figure, when steam generator 20 has been deactivated an optical mechanism 34 may be placed in plenum 28 and suspended from tubesheet 26 by attachment to the open ends of tubes 32. Optical mechanism 34 may comprise an electrically controlled movable reflective mechanism 36 for reflecting radiation, such as light, to various surfaces of the steam generator. For example, reflective mechanism 36 may comprise a plurality of mirrors or prisms attached to the bottom of optical mechanism 34 for reflecting radiation that is directed to those reflective surfaces. Optical mechanism 34 is connected electrically by electrical line 38 to an optical mechanism power supply 40 which may be located remote from steam generator 20 and separated from steam generator 20 by a biological shield 42. In this manner, optical mechanism 34 may be remotely controlled and manipulated so that the operator is not exposed to the radiation field associated with steam generator 20. Optical mechanism power supply 40 provides a means by which optical mechanism 34 may be adjusted so as to change the reflective angles of the mirrors or prisms of reflective mechanism 36 which thereby redirects the radiation that is reflected from the mirrors or prisms to the desired surface to be decontaminated.

A power laser 46 as previously described herein may be arranged near the opening of manway 30 so that the radiation emitted from power laser 46 may be directed toward optical mechanism 34 as shown in the drawing. Power laser 46 may be mounted on a support fixture 48 that is capable of moving power laser 46 relative to manway 30 and relative to optical mechanism 34 for properly aligning the radiation beam emitted from power laser 46. Support fixture 48 may be mounted on a generator platform 50 arranged near the opening of manway 30. Power laser 46 is connected electrically by electrical line 52 to laser power supply 54 located remote from steam generator 20 and behind a biological shield 42.

Power laser 46 may be a laser capable of emitting pulses of radiation with pulse lengths of less than 100 microseconds and preferably less than approximately 1 microseconds in duration. Power laser 46 may also be capable of emitting pulses having a wavelength of less than approximately 12 micrometers and preferably between approximately 0.30 to 1.5 micrometers for typical decontamination applications. In addition, power laser 46 may be capable of producing pulses with energy densities of between 0.5 to 1.5 x 10^3 joules/cm^2 and preferably of approximately 4.5-23 joules/cm^2 at the surface to be decontaminated. Of course, typical optical instruments such as lenses and mirrors may be employed in conjunction with power laser 46 to achieve the desired energy densities at the surface. More specifically, power laser 46 may be a Neodymium YAG pulsed laser capable of emitting pulses of radiation with a wavelength of approximately 1.06 micrometers, an energy output of approximately 0.3 joules/pulse, a pulse length of approximately 30-40 nanoseconds and an energy density of approximately 8-9 joules/cm^2.

A shield plate 56 having an aperture 58 may be bolted to the outside of manway 30 for isolating plenum 28 from the outside of steam generator 20 for containing the radiation removed from the surfaces of plenum 28. Aperture 58 is provided for allowing the radiation beam from power laser 46 to pass therethrough and at optical mechanism 34. A suction mechanism 60 may also be attached to shield plate 56 and extend therethrough into plenum 28 and may extend at the other end to a radioactive waste filtering system 62. Suction mechanism 60 provides a means by which the contamination removed from plenum 28 may be suctioned out of plenum 28 and into a radioactive waste filtering system 62 for disposal of the waste.

In operation, steam generator 20 is deactivated and the reactor coolant is drained therefrom. The manway cover is removed from manway 30 and optical mechanism 34 is suspended from tube sheet 26 either manually or remotely. Shield plate 56 is then attached to manway 30 and power laser 46 is arranged near aperture 58 as shown in the drawing. Next, power laser 46 is activated by laser power supply 54 so that a beam of radiation is emitted from power laser 46 and directed toward the reflective surfaces of optical mechanism 34. From the reflective mechanism 36 of optical mechanism 34, the radiation emitted from power laser 46 is reflected toward the selected surface of the interior of steam generator 20. Power laser 46 may be pulsed with a pulse length of approximately 30-40 nanoseconds and at an energy level of approximately 0.3 joules/pulse so as to impinge the surface to be decontaminated with an energy density of approximately 50-60 joules/in^2. As described previously, the laser radiation is such that it removes an oxide layer of approximately 0.0005 mm. from the surfaces of plenum 28 and thereby reduces the radiation field associated with the oxide film without damaging the base metal. The oxide layer removed is exhausted from plenum 28 by means of suction mechanism 60. As this process continues, optical mechanism 34 is controlled so as to allow the laser beam from power laser 46 to scan all of the surfaces of the interior of plenum 28. In this manner, the entire interior of plenum 28 may be decontaminated. Of course, power laser 46 need not be directed toward optical mechanism 34, but rather it can be aimed directly at the surface to be decontaminated.

Therefore, the invention provides a decontamination method that reduces the radiation field in components of nuclear reactor power plants without damaging the component.

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TELEX 532202 PATOL D

CLAIMS:

1. A method for decontaminating radioactive nuclear components by removing a thin oxide layer of radioactively contaminated metal from the surface of said components thus lowering the radiation level associated with said components characterized in that the surface of said components is scanned by a laser beam of an energy density sufficient to achieve a thermal penetration corresponding to the thickness of said oxide layer and of a width substantially larger than the thickness of said oxide layer.

2. A method according to claim 1, characterized in that the contaminants released from said surface are sucked off and transported away from said component.

3. A method according to claim 2, characterized in that the suction stream is filtered for collecting said contaminants for disposal.

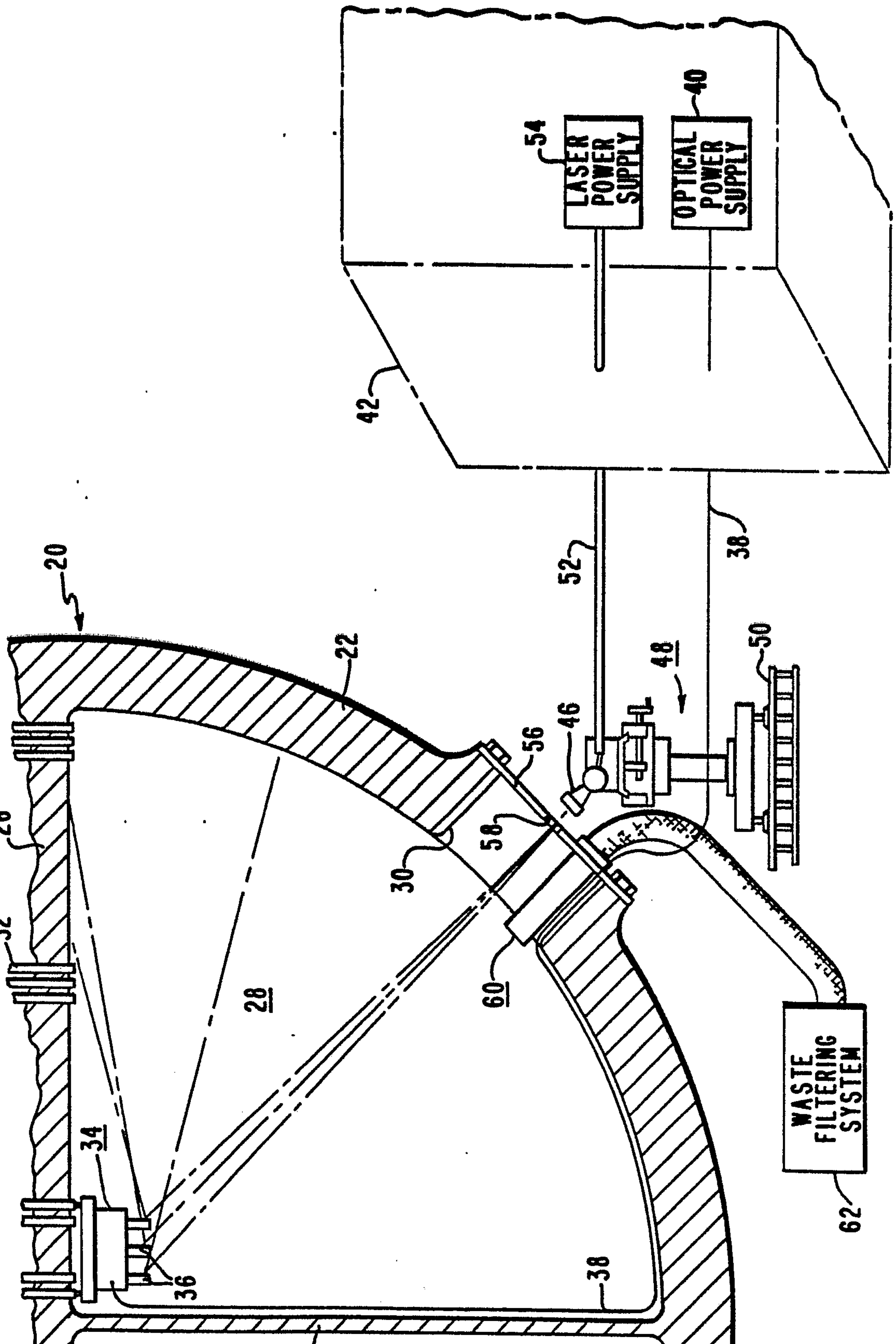
4. A method according to claim 1, 2 or 3, characterized in that said laser has an energy density at said surface of 4.6 to 23 joules/cm^2.

5. A method according to claim 4, characterized in that said laser produces an energy density at said surface of approximately 8.5 joules/cm^2.

6. A method according to claim 5, characterized in that a laser is used which emits pulses of approximately 0.3 joules/pulse with a pulse length of 30-40 nanoseconds and at a wavelength of approximately 1.06 micrometers.

7. A method according to claim 6, characterized in that said laser is a Neodymium YAG pulsed laser.

8. A method according to any of claims 1 to 7, characterized in that the laser beam is directed onto and moved along said surface by a remotely movable reflective mechanism arranged near said component.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LASER POWER SUPPLY
OPTICAL POWER SUPPLY
WASTE FILTERING SYSTEM

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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 83 10 3326

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	FR-A-2 300 632 (ACIERIES REUNIES) * Claims 1,2 * ---	1,2	G 21 F 9/00
A	GB-A-1 382 915 (BRITISH NUCLEAR FUELS) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			G 21 F B 23 K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-07-1983	NICOLAS H.J.F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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E : earlier patent document, but published on, or after the filing date
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