INL/EXT-07-13129

Inspection and Gamma-Ray Dose Rate Measurements of the Annulus of the VSC-17 Concrete Spent Nuclear Fuel Storage Cask

P. L. Winston

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Idaho National Laboratory
Idaho Falls, Idaho 83415

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Approved by:

Name/Title	Date

ABSTRACT

The air-cooling annulus of the Ventilated Storage Cask (VSC)-17 spent fuel storage cask was inspected using a Toshiba 7 mm (1/4”) CCD video camera. The dose rates observed in the annular space were measured to provide a reference for the activity to which the camera(s) being tested were being exposed. No gross degradation, pitting, or general corrosion was observed.

SUMMARY

The air-cooling annulus of the Ventilated Storage Cask (VSC)-17 spent fuel storage cask was inspected using a Toshiba 7-mm (1/4”) CCD video camera. The dose rates observed in the annular space were measured to provide a reference for the activity to which the camera(s) being tested were being exposed. No gross degradation, pitting or general corrosion was observed. This report shows a comparison between images made with a Toshiba EM-QN42H camera with a 4-mm lens, an EVEREST/VIT XLPro video probe with an XLC 1000 SYS Probe and a PXT850SG lens, and a Toshiba Model IK-M44H with a 7.5-mm lens. Video-capture still images taken from the inspection are included, along with data sheets for each of the camera types.

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FIGURES

ACRONYMS

BNFL	British Nuclear Fuels plc
CRIEPI	Central Research Institute of Electric Power Industry
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
MSB	multi-element sealed basket
PWR	pressurized water reactor
SNF	spent nuclear fuel
TAN	Test Area North
VSC	ventilated storage cask

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1. BACKGROUND

Durability of the concrete shielding on a concrete spent nuclear fuel (SNF) storage cask is a key design attribute that dictates the usability of these casks for long-term storage. Radiation and environmental effects may cause chemical alteration of the concrete and could result in excessive cracking, spalling, and loss of compressive strength. The Idaho National Laboratory (INL) and the Central Research Institute of Electric Power Industry (CRIEPI) have been studying the concrete shield performance of the Pacific Sierra Nuclear SNF Ventilated Storage Cask (VSC)-17 because it has been storing SNF for over 15 years as part of a dry cask storage demonstration project.

The VSC-17 ventilated storage cask is a concrete-shielded SNF storage cask system that is designed to contain 17 pressurized water reactor (PWR) fuel elements. It consists of a central steel container, the multi-element sealed basket (MSB), surrounded by a vertical right circular annulus having a wall thickness of 20 in. of concrete. The inner liner of the VSC annulus is A-36 steel that is 89 mm (3.5 in.) thick, which provides structural support and additional shielding. The annular gap between the steel liner and the MSB is 76 mm (3 in.). Transfer of decay heat from the MSB occurs by convective airflow through vents in the concrete shielding component. The inner wall of the concrete shield annulus is steel, which provides structure and additional shielding. The VSC-17 is one of six casks originally stored on the TAN-791 pad at Test Area North (TAN) on the INL site in southeast Idaho. These casks were moved to the Idaho Nuclear Technology and Engineering Center (INTEC) CPP-2707 pad in 2004. The casks were originally assembled as a demonstration project to show the feasibility of dry storage of commercial SNF. The VSC-17 is a product of the Pacific Sierra Nuclear Company, which has since been assimilated into the British Nuclear Fuels plc (BNFL), Solutions Division. The design is unique in that it was scaled down from the commercially produced VSC-24 units. That scale-down was required by the physical limits of the INL cask mover, a six-wheeled straddle carrier that was used for moving the casks from the storage pad to the TAN Hot Shop for loading and maintenance. The cask mover can accommodate a maximum width of 267 cm (105 in.). An as-deployed image of the cask is shown in Figure 1. The upper vents are visible as dark horizontal strips approximately 50 cm (19.7 in.) below the square steel-plate lifting lug that is visible on the right of the top. The vent opening is screened to prevent access to debris or animals. A corresponding lower vent is partially visible through the storage area fence. As designed, the vents are arranged at 90-degree centers offset from the lifting fixtures. As shown in Figure 1, the cask is oriented with the lifting lugs along a north-south line, which is the same orientation as its position on the CPP-2707 pad.

Figure 1. VSC-17 cask on TAN-791 pad September 2003.

The fuel stored in the VSC-17 came from the Florida Power & Light Turkey Point and Virginia Electric Power Company Surry plants. The fuel was originally configured as a 15 × 15-rod array in PWR assemblies. The fuel was repackaged as a part of the Dry Rod Consolidation Technology project into canisters that have the same external dimensions as a PWR assembly (4.3 m [14 ft] × 21.6 cm [8.5 in.] square), but contain 410 rods from deroded assemblies, slightly greater than a two-to-one consolidation ratio for spent fuel rods. The fuel had a nominal heat load of 398 to 685 W (26.8 to 30.5 GWd/tU) per assembly in 1987, prior to deroding.

A visual and radiological survey of the cask was performed in 2003 to determine whether there was a correlation between visible concrete condition and shielding effectiveness. A visual examination of cracking in the storage zone of the cask was performed. A neutron and gamma-ray radiation survey of the fueled zone of the cask was performed with a video camera mounted on the moveable platform that supported the radiation detectors.

No cracks viewed during the survey appear to be other than superficial shrinkage cracks due to curing. Cracking caused by water infiltration is suspected in the case of the area of concrete below the lower vent ports on the north and east sides of the cask. Prevailing winds deposit snow in the vicinity of the vent, and although the vent is maintained clear of obstruction, it appears that freeze-thaw cycles may be promoting cracking.

1.1 2007 Annulus Inspection

On March 21, 2007, a video inspection of the conditions of the annulus between the multi-element sealed basket (MSB) and the concrete shield of the VSC-17 cask was performed on behalf of the Central Research Institute of the Electric Power Industry of Japan.

The video of the inspection is attached to this report. No detectable changes have occurred between 2004 and 2007. The only indications of degradation of the external surface of the MSB are some rust stains that appear to be the result of water, either wind-blown or condensed, running down the side of the steel basket.

Annulus Video Inspection Comparison. Three different cameras were used to inspect the annulus of the VSC-17 cask. Data sheets for the cameras are shown in Appendix A. The first camera used in March 2004 to inspect the annulus was a Toshiba Model EM-QN42H camera with a 4-mm lens. This camera is shown in Figures 2 and 3.

Figure 2. Toshiba video camera.

Figure 3. Toshiba miniature video camera.

In September 2004, the camera used to inspect the annulus was an EVEREST/VIT XLPro video probe with an XLC 1000 SYS Probe and a PXT850SG lens that has a 50-degree field of view and 9–160 mm depth of field. This camera is shown in Figures 4 and 5.

Figure 4. Everest/VIT borescope camera.

Figure 5. Everest/VIT borescope camera.

In March 2007, at the request of CRIEPI, a Toshiba Model IK-M44H with a 7.5-mm lens was used to perform the annulus inspection. This camera is shown in Figure 6.

Figure 6. Toshiba Model EM-QN42H and Everest/VIT borescope cameras compared.

To provide a visual indication of the comparative effectiveness of the cameras, still images taken from the video acquisition are shown below. These images are of approximately similar locations within the annulus, one located near a weld near the top of the MSB, and one near the bottom of the MSB. See Figures 7 through 12.

Toshiba EM-QN42H camera images, March 2004.

Figure 7. Upper annulus.

Figure 8. Lower annulus.

Welch Allyn Everest/VIT borescope images, September 2004.

Figure 9. Upper annulus.

Figure 10. Lower annulus.

Toshiba Model IK-M44H images, March 2007.

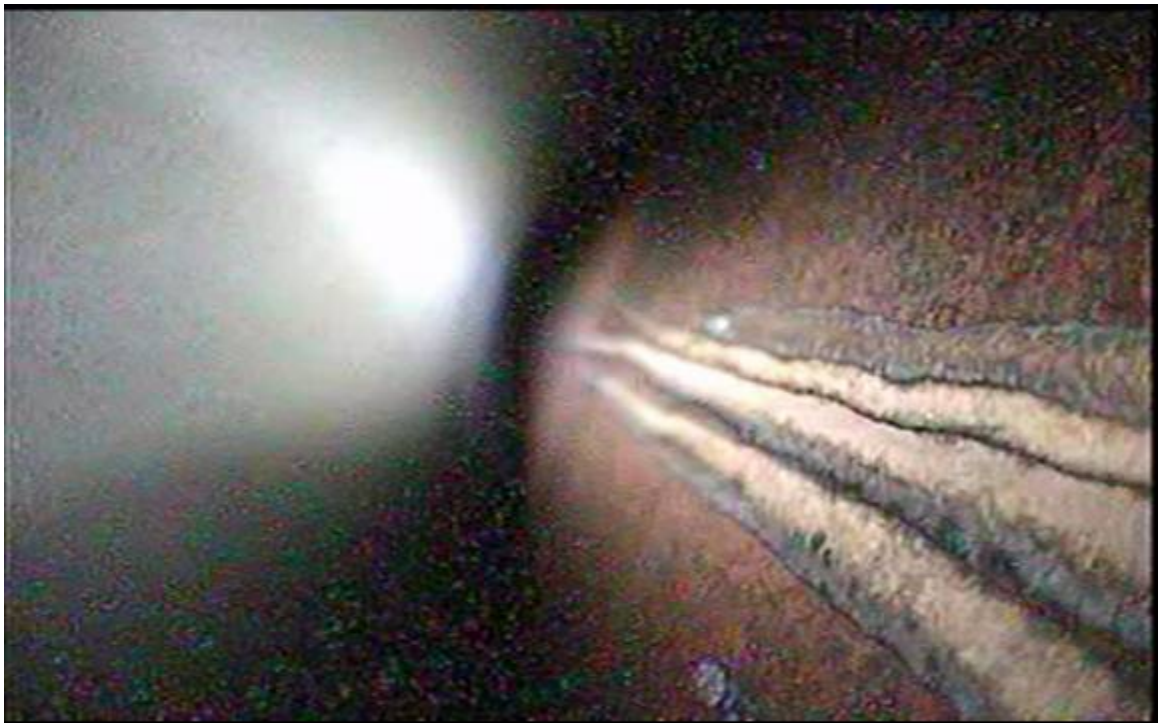


Figure 11. Upper annulus showing condensation stains on multi-element sealed basket (MSB).

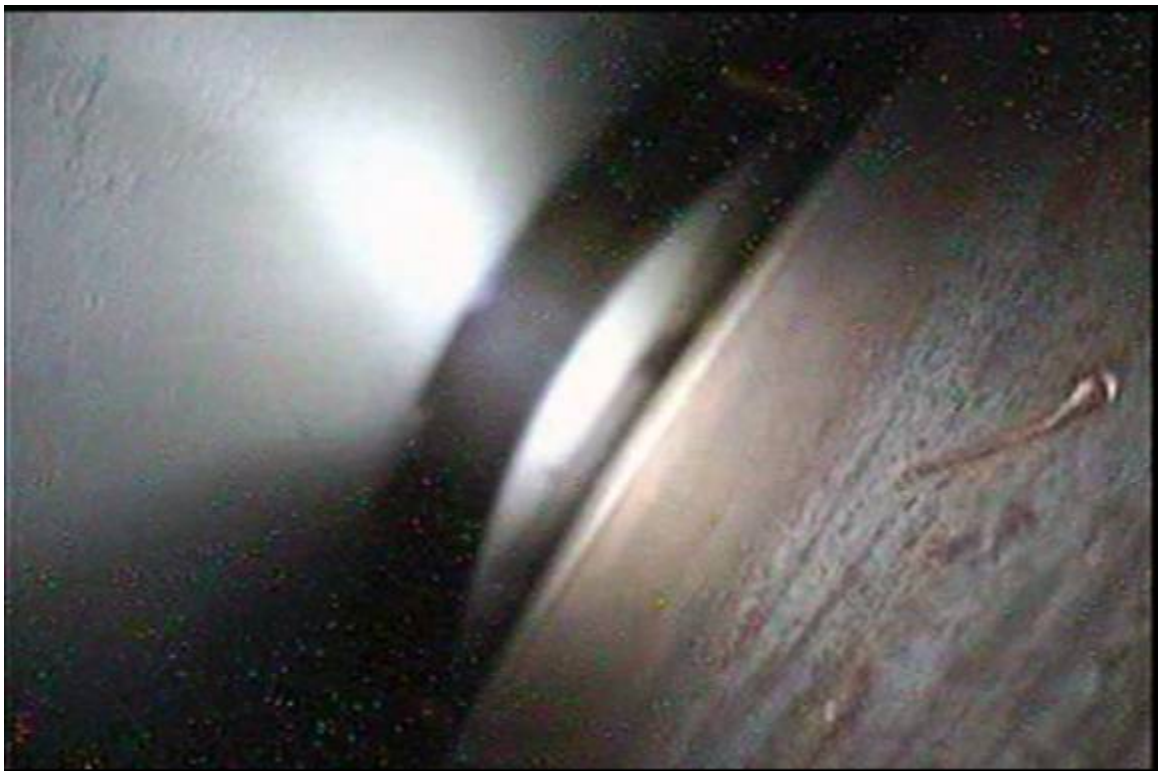


Figure 12. Lower annulus.

1.2 Annulus Radiation Measurements

In addition to the video inspection, a high-range Geiger-Mueller-type gamma-ray detector was inserted into the annulus. The annulus dose rate measurements made in 2004 were limited by the range of the instrument used. The Merlin-Guerin Products (MGP) AMP-100 is limited to 1000 R/h, resulting in only three of the measurements being within the instrument range. An MGP AMP-200 with an operational range of 0–15,000 R/h was acquired for this measurement. The data resulting from this measurement show exceptional correlation between the values measured on the outside of the concrete shield and inside the annulus. The comparison is shown in Figure 13. The gamma-ray detector used is shown in Figure 14.

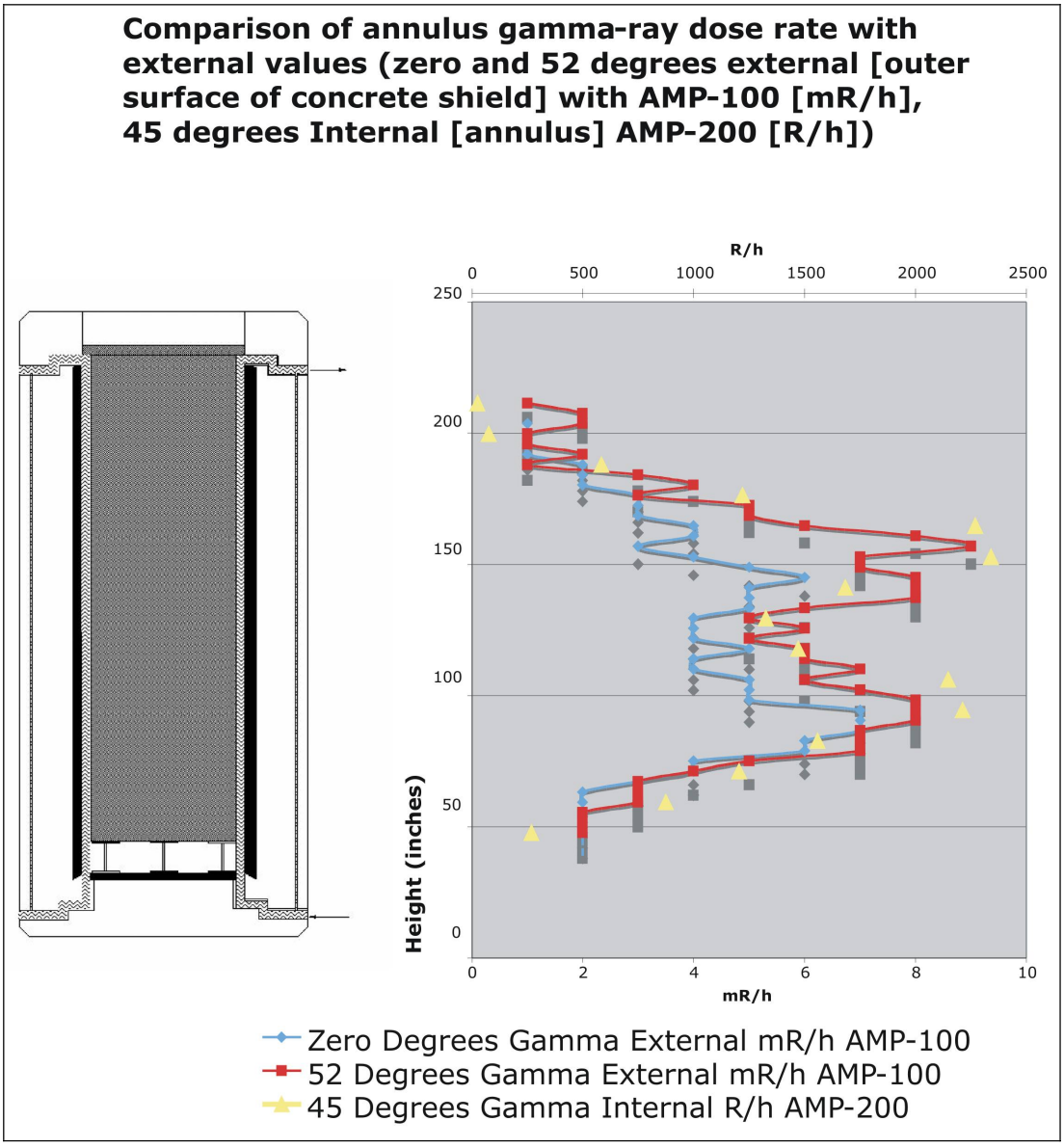


Figure 13. Gamma radiation comparison external–internal.

Figure 14. Amp-200 Geiger-Meuller instrument.

1.3 Inconsistencies in Prior Project Reporting

The initial external radiation measurements were made based on two factors that were inconsistent with prior measurements and the vendor drawings; first was the use of a marking on the cask surface that showed zero degrees to be due south, in line with the southern lifting lug. In fact, the vendor drawings show that zero would be 90-degrees counterclockwise from due south, or due east. This yielded data that were inconsistent for the measurements on the top of the cask for the 180- and 225-degree positions.

Using the design drawing degree positions, the measurements reported for 180 and 225 were actually 270 and 335 degrees. Because all of the cask storage positions are filled, there should be little difference between the readings made in 2003 and those taken in 1991 despite being done at different positions. Figure 15 shows that there is a similar profile between the different measurements.

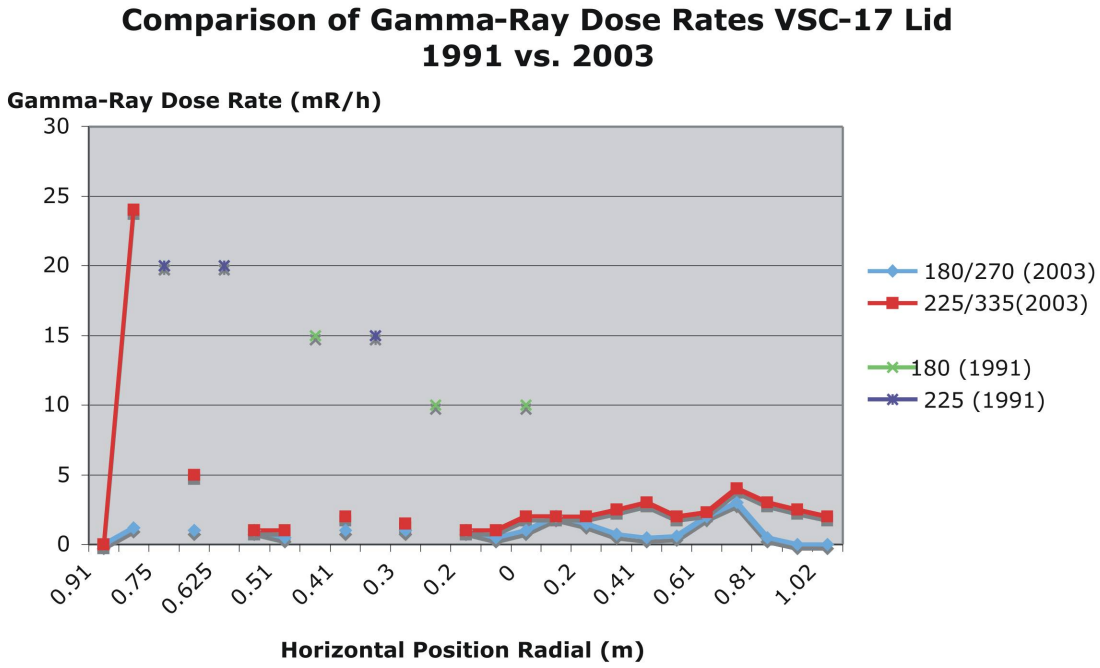


Figure 15. Comparison of gamma-ray dose rates.

The second inconsistency was the use of a progression around the cask making measurements moving counterclockwise. This was a simple expedient of convenience, being the most effective way to move the lift and detectors around the cask with minimum tangling of communications cables.

The issue of greatest concern in the data that were acquired had to do with variation in shielding associated with the 52-degree position (nominally, the 45-degree vent). Fortuitously, the combination of inconsistencies of counterclockwise rotation and starting at due south yields the same reference description. That is to say that whether using the vendor drawing zero of due east and progressing clockwise, or using the field indicated zero of due south and progressing counterclockwise, both approaches reach the same location to be used as 45 degrees. Figure 16 below illustrates this idea.

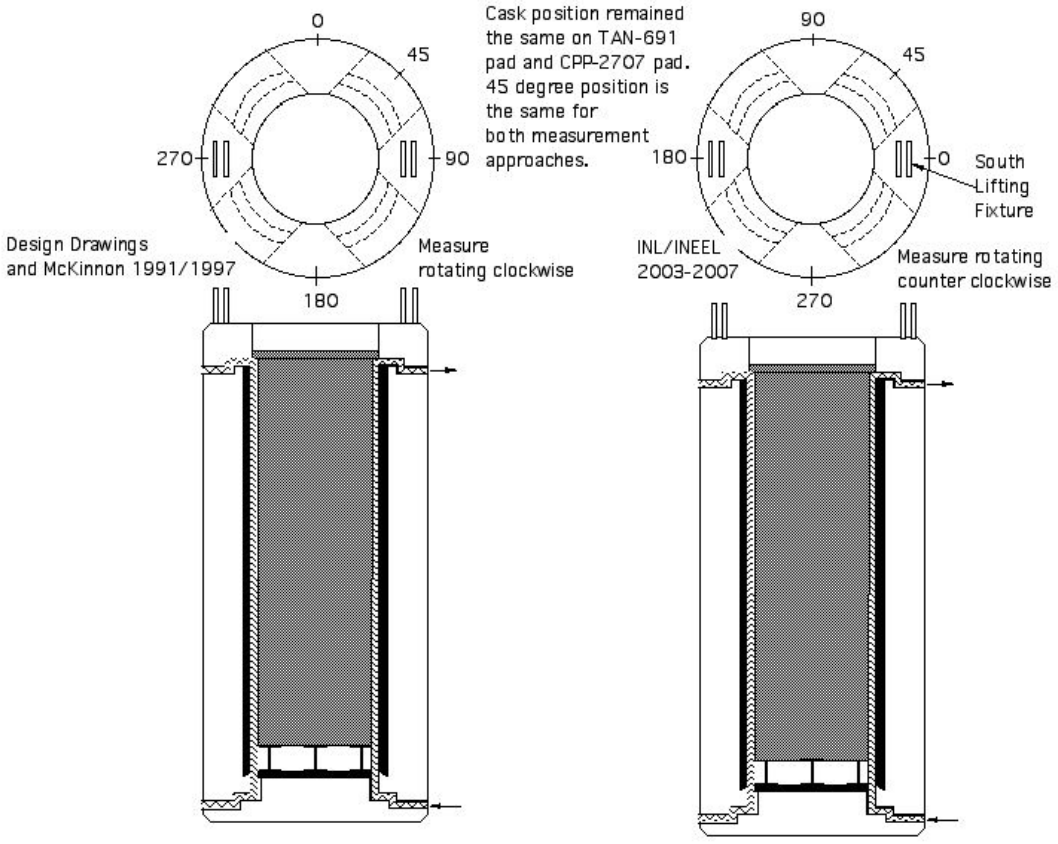


Figure 16. 45-degree/zero-degree reference comparison.

2. LESSONS LEARNED

In 2004, the temperature of the external surface of the cask was measured using a minimally insulated aluminum mast that had 14 thermocouples mounted to make simultaneous contact with the concrete surface. The results were variable, and showed as much as a 7°C (44.6°F) variation between top and bottom thermocouples and different values between the first reading and the last, although both were taken at the due-south nominal zero.

This deviation was determined to be due to a lack of insulation surrounding the thermocouples.

Conclusion: All thermocouples must be thoroughly insulated to assure that convection from exposure to prevailing air circulation does not cause large variations in the apparent surface temperature indication.

3. REFERENCE

1. C. R. Hoffman, P. L. Winston, *Inspection, Gamma Ray and Neutron Dose Rate Measurements on the VSC-17 Concrete Spent Nuclear Fuel Storage Cask*, INEEL/EXT-03-00500, September, 2003.

Appendix A

Camera Data Sheets

Appendix A
Camera Data Sheets

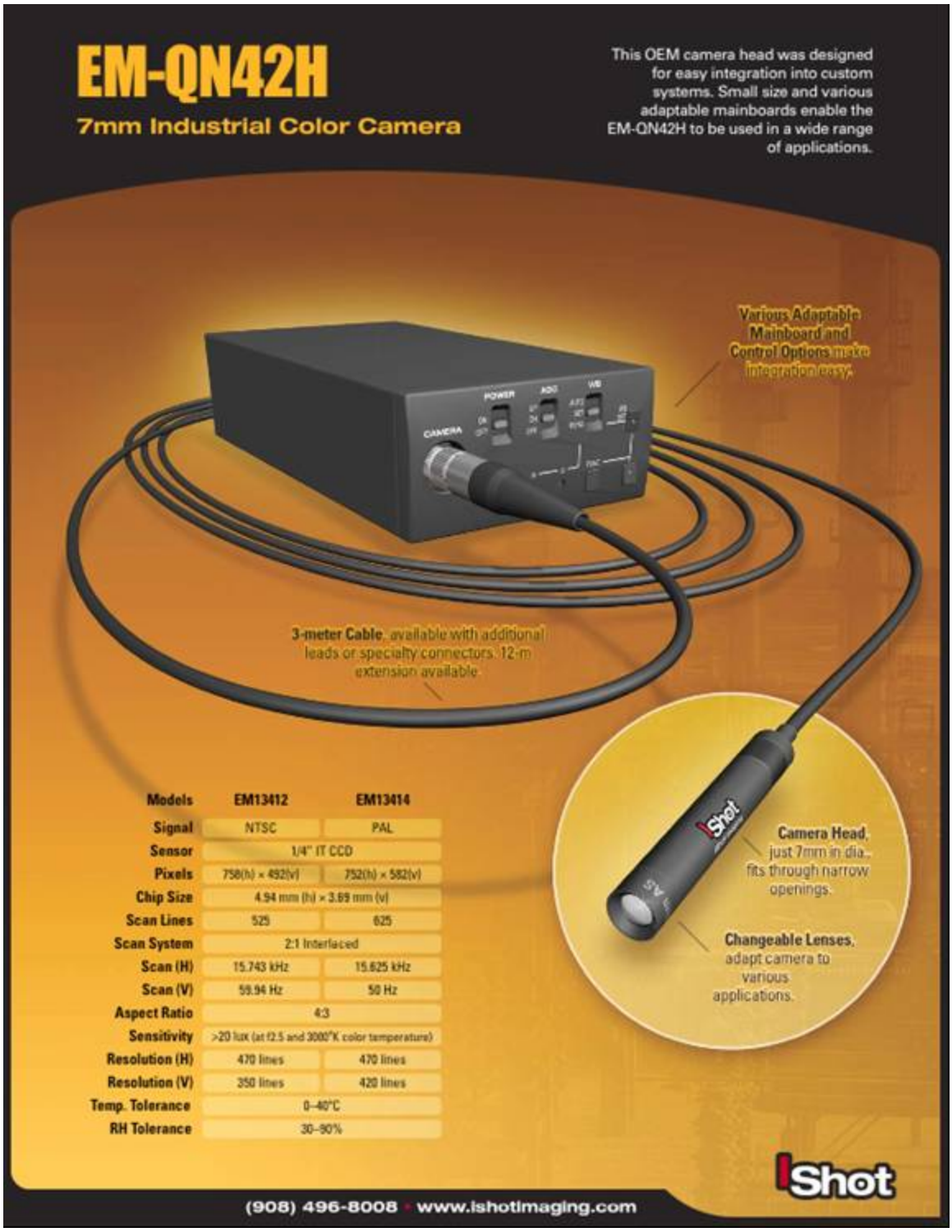


Figure A-1. Data Sheet 1: Toshiba EM-QN42H camera.

Figure A-2. Data Sheet 2: Everest/VIT XL Pro Videoprobe.

TOSHIBA INSTRUCTION MANUAL

MICRO CAMERA HEAD

IK-M44H

INFORMATION
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

USER-INSTALLER CAUTION: Your authority to operate this FCC verified equipment could be voided if you make changes or modifications not expressly approved by the party responsible for compliance to Part 15 of the FCC rules.

This Class A digital apparatus complies with Canadian ICES-003.

Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.

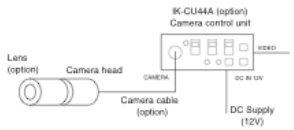
CAUTIONS ON USE

- **Please use this apparatus by connecting only with camera control unit IK-CU44A.**
- Read the "CAUTIONS ON USE AND INSTALLATION" in the instruction manual of IK-CU44A, and follow them.

COMPONENTS

(1) Camera head (without lens) 1
(2) Accessories
(a) Camera holder 1
(b) Instruction manual 1

CONNECTION



- When connecting or disconnecting the camera cables (for the camera head and camera control unit), always turn off the power switch of the camera control unit first. If not, the camera head may be damaged.

SPECIFICATIONS

Image sensor	1/2 inch IT-CCD
Effective pixels	Horizontal: 768 pixels, Vertical: 494 pixels
Effective image area	Horizontal: 6.54 mm, Vertical: 4.89 mm
Resolution	Horizontal: More than 470 lines, Vertical: More than 350 lines
Standard intensity of illumination for objects	30 lx (F1.6, 3000K)
Minimum intensity of illumination for objects	2.5 lx (F1.6, 3000K)
Weight	0.6 oz (18g)

- Design and specifications are subject to change without notice.

OPTIONAL PARTS

For further details, contact your camera dealer.

Camera control unit

Type name
IK-CU44A

Lens

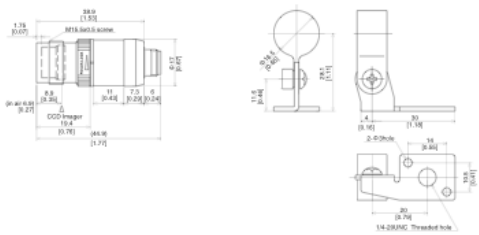
Type name	Focal length mm	F stop
JK-L03M	3.0	1.8
JK-L04M2	4.5	2.0
JK-L7SM	7.5	1.6
JK-L15M2	15.0	2.0
JK-L24M2	24.0	3.1

Camera cable

Type name	Nominal length m	Diameter mm
EXC-4302	2	5.0
EXC-4303	3	5.0
EXC-4305	5	5.0
EXC-4312	12	5.0
EXC-4320	20	5.0
EXC-4330	30	5.0

EXTERIOR DIMENSIONS

Camera Head Camera Holder Unit : mm [inch]
ø : diameter



LIMITED WARRANTY
TOSHIBA CCD CAMERA

Promptly register your product with Toshiba on-line at www.toshiba.com/taisisd. By registering your product you will be eligible for periodic updates, announcements, and special offers. You will have access to extended warranty options, upgrades (as applicable), useful tips, on-line troubleshooting, and the ability to schedule service on-line if necessary. The Imaging Systems Division of Toshiba America Information Systems, Inc. ("ISD") makes the following limited warranties. These limited warranties extend to the Original End-User ("Your/[r]").

Limited One (1) Year Warranty of Labor and Parts
ISD warrants this product and parts against defects in material or workmanship for a period of one year from the date of original retail purchase by the end-user. During this period, ISD will repair or replace a defective product or part with a new or refurbished item. The user must deliver the entire product to an ISD authorized service center. The user is responsible for all transportation and insurance charges for the product to the Service Center. ISD reserves the right to substitute Factory Refurbished Parts and / or Factory Refurbished Product in place of those in need of repair.

Step-by-step Procedures - How to Obtain Warranty Service
[1] Verify operation of the unit by checking the instruction manual
[2] If there is a defect in material or workmanship, contact an Authorized Service Provider within 30 days after the product fails to comply with specifications.
[3] Arrange for delivery of the product to the ISD authorized service center. Products must be insured and securely packed, preferably in the original shipping carton. A letter explaining the defect and a copy of the bill of sale or other proof of purchase must be enclosed with a complete return street address and daytime telephone number. Charges for transportation and insurance must be prepaid by the end-user.

Questions? If you have any questions, please check the Toshiba Imaging Systems Division Web site as follows:

Website: http://www.toshiba.com/taisisd/indmed

Your Responsibility, warranties are subject to the following conditions:
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[2] You must schedule service within thirty days after you discover a defective product or part.
[3] All warranty servicing of this product must be made by a Toshiba ISD Authorized Service Provider.
[4] The warranty extends to defects in material or workmanship as limited above, and not to any products or parts that have been lost or discarded by user. The warranty does not cover damage caused by misuse, accident, improper installation, improper maintenance, or use in violation of instructions furnished by ISD. The warranty does not extend to units which have been altered or modified without authorization of ISD, or to damage to products or parts thereof which have had the serial number removed, altered defaced or rendered illegible.

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Imaging Systems Division
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2. Malfunction or non-function resulting in indirect, additional or consequential damages, including but not limited to loss of expected income and suspension of business activities.
3. Incorrect use not in compliance with instructions in this instruction manual.
4. Malfunctions resulting from misconnection to other equipment.
5. Repairs or modifications made by the user or caused to be made by the user and carried out by an unauthorized third party.
6. Notwithstanding the foregoing, Toshiba's liabilities shall not, in any circumstances, exceed the purchase price of the product.

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There may be a conflict with the Copyright Law and other laws when a customer uses, displays, distributes, or exhibits an image picked up by a television camera without permission from the copyright holder. Please also note that transfer of an image or file covered by copyright is restricted to use within the scope permitted by the Copyright Law.

CAUTIONS ON USE AND INSTALLATION

- **Carefully handle the units.**
  Do not drop, or give a strong shock or vibration to the camera. This may cause problems. Treat the camera cables carefully to prevent cable problems, such as cable breakdown and loosened connections.
- **Do not shoot intense light.**
  If there is an intense light at a location on the screen such as a spot light, a blooming and smearing may occur. When intense light enters, vertical stripes may appear on the screen. This is not a malfunction. Ghosts may occur when there is an intense light near the object. In this case, change the shooting angle.
- **Install the camera in a location free from noise.**
  If the camera or the cables are located near power utility lines or a TV, etc. undesirable noise may appear on the screen. In such a case, try to change the location of the camera or the cable wiring.
- **Moire**
  When thin stripe patterns are shot, stripe patterns that are not actually there (moire) may appears as interference stripes. This is not a malfunction.
- **Operating ambient temperature and humidity.**
  Do not use the camera in places where temperature and humidity exceed the specifications. Picture quality will lower and internal parts may be damaged.
  Be particularly careful when using in places exposed to direct sunlight. When shooting in hot places, depending on the conditions of the object and the camera (for example when the gain is increased), noise in the form of vertical strips or white dots may occur. This is not a malfunction.
- **Handling of the protection cap.**
  Keep the protection cap away from children. Children may put them into mouth or swallow them accidentally. The protection cap protects the image sensing plane when the lens is removed from the camera, do not throw away.
- **When not using the camera for a longtime.**
  Stop supplying power.
- **When cleaning the camera**
  Always turn off the power and clean with a piece of soft dry cloth. Do not use benzine, alcohol, thinner, household detergents, chemically treated cloths, etc. If used, coating and printed letters may be discolored. When cleaning the lens, use a lens cleaning paper, etc.
- **Avoid using or storing the camera in the following places:**
  Places filled with highly flammable gas.
  Places near gasoline, benzene, or paint thinner.
  Places subject to strong vibration.
  Places contacting chemicals (such as pesticides), rubber or vinyl products for a long period of time.

Figure A-3. Data Sheet 3: Toshiba Model IK-M44H.

Appendix B

Gamma-Ray Dose Rate Data Internal Survey

Appendix B
Gamma-Ray Dose Rate Data Internal Survey

Distance from bottom (ft)	R/h Amp-200 Detector 2007	R/h Amp-100 Detector 2004
15	268	266.7
14	875	821.5
13	1205	>1000
12	1559	>1000
11	2213	>1000
10	2147	>1000
9	1472	>1000
8	1326	>1000
7	1684	>1000
6	2340	>1000
5	2269	
4	1220	960
3	585	671
2	75	99.8
1	25	

External VSC-17 lid gamma–ray dose rate data comparison 2003 vs. 1991.

Gamma Ray Dose Rates Interpreted from 2003 and 1991 graphics	Figure 8. INEEL/ EXT-03-0500			Dose Rate @ Contact, Graphic EG&G EDF 3.2.31	
	2003			1991	
Lid Position (m)	180/270 (2003)	225/335 (2003)		180 (1991)	225 (1991)
0.91	0	0			
0.81	1.2	24			
0.75				20	20
0.71	1	5			
0.625				20	20
0.61	1	1			
0.51	0.5	1			
0.47				15	
0.41	1	2			
0.35					15
0.3	1	1.5			
0.25				10	
0.2	1	1			
0.1	0.5	1			
0	1	2		10	
0.1	2	2			
0.2	1.5	2			
0.3	0.75	2.5			
0.41	0.5	3			
0.51	0.6	2			
0.61	2	2.3			
0.71	3	4			
0.81	0.5	3			
0.91	0	2.5			
1.02	0	2			