**MITSUBISHI HEAVY INDUSTRIES, LTD.**
**16-5, KONAN 2-CHOME, MINATO-KU**
**TOKYO, JAPAN**

April 25, 2013

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF- 13100

**Subject:** **MHI's Second Revised Response to US-APWR DCD RAI No. 758-5680 Revision 0 (SRP 03.05.03)**

**References:** 1) "Request for Additional Information No. 758-5680 Revision 3, SRP Section 03.05.03 – Barrier Design Procedures - Application Section: 3.5.3", dated May 16, 2011.
2) "MHI's Response to US-APWR DCD RAI No. 758-5680 Revision 0 (SRP 03.05.03)", UAP-HF-11424, dated December 9, 2011.
3) "MHI's Revised Response to US-APWR DCD RAI No. 758-5680 Revision 0 (SRP 03.05.03)", UAP-HF-13025, dated February 6, 2013.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "MHI's Second Revised Response to Request for Additional Information No. 758-5680 Revision 0."

Enclosed is the second revised response to Question 03.05.03-10 contained within Reference 1. This response supersedes the previous responses to Question 03.05.03-10 in Reference 2 and 3 in their entirety, reflecting results of the conference call with the NRC on February 20, 2013. Major update is clarification for the minimum wall thickness based on local effect calculation of automobile missile.

As indicated in the enclosed materials, this document contains information that MHI considers proprietary, and therefore should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential. A non-proprietary version of the document is also being submitted with the information identified as proprietary redacted and replaced by the designation "[ ]".

This letter includes a copy of the proprietary version (Enclosure 2) of the response, a copy of the non-proprietary version (Enclosure 3) of the response, and the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all materials designated as "Proprietary" in Enclosure 2 be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

Please contact Mr. Joseph Tapia, General Manager of Licensing Department, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is below.

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NRO

Sincerely,

Y. Ogata

Yoshiki Ogata,
Executive Vice President
Mitsubishi Nuclear Energy Systems, Inc.
On behalf of Mitsubishi Heavy Industries, Ltd.

Enclosure:

1. Affidavit of Yoshiki Ogata

2. MHI's Second Revised Response to Request for Additional Information No. 758-5680 Revision 0 (Proprietary version)

3. MHI's Second Revised Response to Request for Additional Information No. 758-5680 Revision 0 (Non-proprietary version)

CC: J. A. Ciocco
J. Tapia

Contact Information
Joseph Tapia, General Manager of Licensing Department
Mitsubishi Nuclear Energy Systems, Inc.
1001 19th Street North, Suite 710
Arlington, VA 22209
E-mail: joseph_tapia@mnes-us.com
Telephone: (703) 908 – 8055

ENCLOSURE1

Docket No. 52-021
MHI Ref: UAP-HF-13100

**MITSUBISHI HEAVY INDUSTRIES, LTD.**

**AFFIDAVIT**

I, Yoshiki Ogata, state as follows:

1. I am Executive Vice President of Mitsubishi Nuclear Energy System, Inc. and have been delegated the function of reviewing MITSUBISHI HEAVY INDUSTRIES, LTD's ("MHI") US-APWR documentation to determine whether it contains information that should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4)as trade secrets and commercial or financial information which is privileged or confidential.

2. In accordance with my responsibilities, I have reviewed the enclosed document entitled "MHI's Second Revised Response to Request for Additional Information No. 758-5680 Revision 0" dated April 2013, and have determined that portions of the document contain proprietary information that should be withheld from public disclosure. Those pages containing proprietary information are identified with the label "Proprietary" on the top of the page and the proprietary information has been bracketed with an open and closed bracket as shown here "[ ]". The first page of the document indicates that all information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The information identified as proprietary in the enclosed document has in the past been, and will continue to be, held in confidence by MHI and its disclosure outside the company is limited to regulatory bodies, customers and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and is always subject to suitable measures to protect it from unauthorized use or disclosure.

4. The basis for holding the referenced information confidential is that it describes the unique design and methodology developed by MHI for performing the plant design of US-APWR.

5. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of information to the NRC staff.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information. Other than through the provisions in paragraph 3 above, MHI knows of no way the information could be lawfully acquired by organizations or individuals outside of MHI.

7. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without incurring the costs or risks associated with the design of the subject systems. Therefore, disclosure of the information contained in the referenced document would have the following negative impacts on the competitive position of MHI in the U.S. nuclear plant market:

A. Loss of competitive advantage due to the costs associated with development of the thermal design. Providing public access to such information permits competitors to duplicate or mimic the methodology without incurring the associated costs.

B. Loss of competitive advantage of the US-APWR created by benefits of enhanced plant safety, and reduced operation and maintenance costs associated with the thermal design.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information and belief.

Executed on this 25th day of April, 2013.

Y. Ogata

Yoshiki Ogata,
Executive Vice President
Mitsubishi Nuclear Energy Systems, Inc.

Enclosure 3

UAP-HF-13100
Docket No. 52-021

MHI's Second Revised Response to Request for Additional Information No. 758-5680 Revision 0

April 2013
(Non-Proprietary)

# RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

**4/25/2013**

**US-APWR Design Certification**

**Mitsubishi Heavy Industries**

**Docket No. 52-021**

| | |
|---|---|
| **RAI NO.:** | **NO. 758-5680 REVISION 0** |
| **SRP SECTION:** | **03.05.03 – Barrier Design Procedures** |
| **APPLICATION SECTION:** | **3.5.3** |
| **DATE OF RAI ISSUE:** | **05/16/2011** |

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**QUESTION NO. RAI 03.05.03-10:**

In the response to RAI 686-4557, the applicant stated the following:

"With respect to item (2) global damage in the RAI question: Design for building "tipover" and foundation sliding failure are dominated by the seismic design load combinations, not by load combinations involving tornado missiles. For example, the heaviest missile, which is the 4000 lb automobile missile, is about 0.013% of the weight of a Power Source Building, which weighs roughly 30,000,000 lb (Reference MHI Technical Report MUAP-10001, "Seismic Design Bases of the US-APWR Standard Plant", Revision 2, Table 5.4.2-1). Due to this small ratio, lateral building load due to transfer of the automobile missile kinetic energy will have negligible impact on "tip-over" and sliding. This ratio is even less for the PCCV, which weighs roughly 70,000,000 lb (shell cylinder and dome portions only)"

Based on the above information, the building "tip-over" and foundation sliding failure are indeed bounded by the design-basis seismic loadings. However, the impact loading by the automobile missile (> 500 Hz, high pulse) imposes a different structural response from seismic loading (<33 Hz, inertia force induced, quasi-static). Thus, the seismic analysis methodology may not apply directly in this case. One of the major differences is the applied load distribution wherein the impact force induced by the auto missile at the impact site is much bigger than the inertia force induced at that location locally by the SSE, even though the overall seismic loads are higher. Accordingly, the local effects induced by the localized dynamic impact load can still affect the structural integrity at or near the impact location of the building.

DCD Rev. 2 Tier 2, Section 3.5.1.4 on Page 3.5-11 states that "all seismic category I structures are capable of withstanding the impact of each identified tornado missile at any elevation, including the potential impact of a 4,000 pound automobile greater than 30 feet above grade." Thus, the staff requests investigations of local impact effects to assure structural integrity of all seismic category I structures under a automobile missile striking at any elevation. The analyses should include local shear response of the building at the critical elevation level near the auto missile impact site as well as the possibility of the auto missile penetrations at the weakest locations wherever the missile can strike. It should be noted that the case of auto missile impact at elevations higher than 30 ft. above grade is not covered by RG 1.76, thus not addressed in Item (1) of the response to RAI 686-4557.

**ANSWER (REVISION 2):**

Local Impact Loading Due to Automobile Missile

The Reactor Building (R/B), east Power Source and west Power Source Buildings (east and west PS/B) walls and roof slabs are evaluated for the effect of the automobile missiles as described in Subsection 3.8.4.3.5.2 (as well as other design-basis tornado-generated missiles described in DCD Subsection 3.5.1.4). The currently provided minimum thicknesses of the R/B and PS/B Building walls and roof slabs are larger than the values calculated for penetration, perforation and scabbing due to any design basis tornado missiles, and higher than the minimum thicknesses provided in Table 1 of SRP 3.5.3 per the description of Subsection 3.5.3.1.

The effect of the automobile impact on the walls and slabs is evaluated using two methods: one method using formulation based on "no penetration" as described in Williamson and Alvy, "Impact Effect of Fragments Striking Structural Elements" (DCD Reference 3.3-6), and a time history method, assuming an almost constant impact force based on the crashing load of the missile with no penetration. The calculated ductility values conform to the requirements in DCD Subsection 3.5.3.2. The ultimate load capacities of the walls and slab panels in direct shear are shown to be larger than the impact load or the flexural capacity (whichever is less) increased by a factor of 1.2 (DCD References 3.5-16 and 3.5-9). The evaluation was performed using a tornado intensity level based on a Region I tornado (230 mph) (Ref. RG 1.76, Figure 1, March, 2007). The missiles considered in the evaluation include a 4,000 lb automobile, the 287 lb schedule 40 pipe and the 0.147 lb solid steel sphere as called for in Table 2, RG 1.76, March 2007.

The force on the R/B complex from the impact of an automobile tornado missile is used in the evaluation of the global effect of an automobile impact on the R/B. It is shown that the effect of an automobile impacting the R/B will not govern the R/B design. The maximum horizontal impact load, using a dynamic load factor of 2, is used. This load is equal to 951 kips. This load is derived from a time history forcing function of an automobile crash under frontal impact. The automobile is the deformable missile, and the object (structure) impacted is a rigid target. It is the same forcing function that was used in the evaluation of the R/B complex for the tornado missile automobile impact above 30'.

The automobile is considered to impact the R/B at the lowest roof level (EL 101'). This location is chosen so that the largest shear at the lowest roof (EL 101') and maximum moment at the connection to the top of the basemat (EL 3' – 7") is obtained. The resulting shear and moment are compared to the seismic demand (shear and moment) at same location.

The shear at the top of the basemat due to automobile tornado impact loads at the lowest roof (EL 101') is:

Shear = 475.5 x 2 = 951 kips

The moment at the top of the basemat due to automobile tornado impact loads at the PCCV location is:

Moment = 951 kips x (101' - 3'-7") = 951 kips x (97'-5") = 92,643 k-ft

Based on the SASSI Finite Element (FE) Model used for the current basic design of the R/B complex, the total seismic forces in both horizontal directions were calculated and are shown below. It should be noted that the results used for the seismic moment will be on the

conservative side since the response spectrum analysis output, which was used, does not differentiate between positive and negative in the output (forces are all positive or all negative).
In addition, the results of the tornado missile impact forces, taken from the tornado missile calculation cited above, are compared to maximum seismic forces and moments in the table below:

Table-1: Summary of Force and Moments from Seismic and Tornado Missile

| | **Horizontal "X"** | **Horizontal "Y"** |
|---|---|---|
| **Seismic Force** | 436,800 kips | 408,900 kips |
| **Seismic Moment** | 14,824,780 ft-kip | 11,168,620 ft-kip |
| **Tornado Missile Force (2x calculated load at el. 3'-7")** | 951 kips | 951 kips |
| **Tornado Missile Moment (based on 97'-5" above grade-R/B low roof level)** | 92,643 ft-kip | 92,643 ft-kip |

Note: Max loads selected.

Comparing the seismic demand to the tornado load, the following ratios are determined:

Seismic Load /Tornado Load = 408,900 / 951 = 430
Seismic Moment / Tornado Moment = 11,168,620 / 92,643 = 120

The ratios of loads and moments reflect that the overall seismic design of the Standard Plant governs over the overall tornado missile effects on the Standard Plant. Therefore, the effect of the tornado missile impact on the overall structure of the R/B complex is bounded.

For the local effect of the tornado missile on the Standard Plant, several specific areas were evaluated. The results of the local evaluation are as follows:

Table-2: Required and Actual Thicknesses for Walls and Roofs Against Region I Automobile Tornado Missiles

| | **Minimum Wall Thickness Required per NUREG-0800, SRP 3.5.3** | **Minimum R/B Wall Thickness Required per Calculation** | **Current Design Thickness** |
|---|---|---|---|
| **Wall (R/B and PS/B)** | 16.0 inches | [ ] | [ ] |
| **Roof (R/B and PS/B)** | 11.7 inch | [ ] | [ ] |

Based on the above, the wall and roof slab thicknesses provided are well above the minimums required per NUREG-0800, SRP 3.5.3.

Shear capacities of the walls were also checked for tornado missile impact loads. The results show that the ultimate shear capacities of the walls and slabs are larger than the minimum requirement for the impact load. The punching shear capacities of the walls and slabs for automobile missile impact were calculated and the results show that the wall and slab capacities are greater than the applied loads. The punching shear capacity for the pipe missile impact load was not performed based on the article by R.P. Kennedy, "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects". Also, in accordance with Section F.7.2.3 of ACI 349-06, Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary, the design for punching shear is not required when the concrete thickness is at least 20% greater than that required to prevent perforation. Since the wall and slab thicknesses are more than 20% of the thicknesses required for perforation, punching shear of the 6.625" diameter pipe missile is not required. These wall thicknesses are provided in the Standard Plant calculation referenced at the beginning of this section.

Please note that for clarity, a cross-reference to the tornado loading requirements discussed in DCD Subsections 3.3.2 and 3.8.4 will be added to DCD Subsection 3.5.1.4 as indicated below in "Impact on DCD".

<u>Elevation of Automobile Missile</u>

In response to the NRC comment in the last sentence of the RAI question, please note that RG 1.76 states:

> "The automobile missile is considered to impact at all altitudes less than 30 feet (9.14 meters) above all grade levels within 0.5 mile (0.8 kilometer) of the plant structures."

Site-specific conditions may exist where grades within 0.5 mile of plant structures may be elevations higher than grades immediately adjacent to standard plant structures, therefore the automobile missile may potentially impact SSCs at elevations more than 30 feet above standard plant grade up to the lowest roof level of R/B surrounding PCCV, which is 98'-5" above the grade.

Therefore, the potential for automobile missiles to impact at elevations higher than 30 feet above grade is a requirement in RG 1.76, and this requirement is addressed in the response to RAI 686-4557 (ML110620099), and DCD Subsection 3.5.1.4.

For the US-APWR standard plant, the lowest roof elevation of the R/B surrounding PCCV is a plant elevation 101'-0". Based on plant grade elevation 2'-7", the minimum height of the R/B roof to the PCCV is 98'-5" above grade. In order to accommodate automobiles at all grade levels up to 98'-5" within 0.5 mile of the plant structures, any site-specific grading within 0.5 mile of the structures is limited to 68'-5" without a site-specific evaluation or departure from the DCD.

**Impact on DCD**

See the Attachment 1 mark-up of DCD Tier 2, Subsection 3.5, changes to be incorporated. The last paragraph in DCD Subsection 3.5.1.4 will be revised to read as follows:

> "A 4,000 pound automobile, 16.4 ft by 6.6 ft by 4.3 ft, impacting the structure at normal incidence with a horizontal velocity of 135 ft/s or a vertical velocity of 85 ft/s. To accommodate site-specific conditions where grades within 0.5 mile of plant structures may have elevations higher than grade at the structures, this missile is considered to potentially impact SSCs at any azimuthal direction and at any elevation up to the lowest roof level of the R/B surrounding PCCV, which is 98'-5" above grade at the maximum hurricane missile velocity stated above."

"Openings through the exterior walls of the seismic category I structures, and the location of equipment in the vicinity of such openings, are arranged so that a missile passing through the opening would not prevent the safe shutdown of the plant and would not result in an offsite release exceeding the limits defined in 10 CFR 100 (Reference 3.5-2). Otherwise, structural barriers are designed to resist tornado missiles in accordance with the design procedures discussed in Subsection 3.5.3. Tornado missiles are not postulated to ricochet or strike more than once at a target location. Tornado missile protection is provided to resist the normal component of force delivered by the missile striking in any direction. Additional tornado loading design requirements are addressed in Subsections 3.3.2 and 3.8.4. Due to the robustness of the exterior wall design, all seismic category I structures other than PCCV are designed to withstand the impact of each identified tornado missile at any elevation, including the potential impact of a 4,000 pound automobile greater than 30 feet above grade, up to a total height of 98'-5" above grade."

**Impact on R-COLA**

There is no impact on the R-COLA.

**Impact on S-COLA**

There is no impact on the S-COLA.

**Impact on PRA**

There is no impact on the PRA.

**Impact on Technical/Topical Report**

There is no impact on a Technical/Topical Report.

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This completes MHI response to the NRC question.

conservative estimate than for a favorably oriented single unit and in conformance with the guidance in SRP Section 3.5.1.3. This conservative estimation provides the flexibility for the orientation of site-specific SSCs of concern based on the guidance of RG 1.117 (Reference 3.5-19) and RG 1.115 (Reference 3.5-6). The determination of $P_1$ (probability of turbine failure resulting in the ejection of turbine rotor (or internal structure) fragments through the turbine casing) is strongly influenced by the program for periodic inservice testing and inspection. Criteria as described in NUREG-0800 Standard Review Plan 3.5.1.3, Table 3.5.1.3-1 (Reference 3.5-7) correlates $P_1$ to operating cases necessary to obtain $P_4$ in an acceptable risk rate of $10^{-7}$ per year, where $P_1$ is less than $P_4 / (P_2 \times P_3)$ or $10^{-4}$. The $P_1$ applicable to the US-APWR is described in Subsection 10.2.2. The COL Applicant is to commit to actions to maintain $P_1$ within this acceptable limit as outlined in RG 1.115, "Protection Against Low-Trajectory Turbine Missiles" (Reference 3.5-6) and SRP Section 3.5.1.3, "Turbine Missiles" (Reference 3.5-7). Reports MUAP-07028-NP, "Probability of Missile Generation From Low Pressure Turbines" (Reference 3.5–17) and MUAP-07029-NP, "Probabilistic Evaluation of Turbine Valve Test Frequency" (Reference 3.5-18) are to be used to establish programs and criteria for preservice inspection, inservice inspection interval and turbine valve test frequency in order to maintain the turbine missile generation probability, $P_1$, less than the acceptable limit of $1 \times 10^{-5}$ per year. Inservice inspection programs are to be maintained as outlined in SRP 3.5.1.3, Section II, Acceptance Criteria, Section 4 (Reference 3.5-7).

### 3.5.1.4 Missiles Generated by Tornadoes and ~~Extreme Winds~~Hurricanes DCD_02-03 S01

The US-APWR design basis spectrum of tornado missiles conforms to the spectrum of missiles defined in Table 2 of "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants", RG 1.76, Rev.1 (Reference 3.5-8) for a region I tornado, the most severe. The spectrum of missiles is chosen to represent: (1) a massive high-kinetic-energy missile that deforms on impact, (2) a rigid missile that tests penetration resistance, and (3) a small rigid missile of a size sufficient to pass through any opening in protective barriers.

Therefore, the spectrum of tornado missiles is as follows:

- A 4,000 pound automobile, 16.4 ft by 6.6 ft by 4.3 ft, impacting the structure at normal incidence with a horizontal velocity of 135 ft/s or a vertical velocity of 90.5 ft/s. To accommodate site-specific conditions where grades within 0.5 mile of plant structures may have elevations higher than grade at the structures, this missile is considered to potentially impact SSCs at any azimuthal direction and at any elevation up to the lowest roof level of R/B surrounding PCCV, which is 98'-5" above grade, at the maximum tornado missile velocity stated above.~~This missile is considered to potentially impact at all plant elevations up to 30 ft above grade for all grades within 0.5 mile of the plant structures.~~ DCD_03.05.03-9 DCD_03.05.03-10 S01 DCD_03.05.03-9

- A 6.625 inch diameter by 15 ft long schedule 40 pipe, weighing 287 pounds, impacting the structure end-on at normal incidence with a horizontal velocity of 135 ft/s or a vertical velocity of 90.5 ft/s.

- A 1 inch diameter solid steel sphere assumed to impinge upon barrier openings in the most damaging direction with a horizontal velocity of 26 ft/s or a vertical velocity of 17.4 ft/s.

The US-APWR design basis spectrum of hurricane missiles conforms to the spectrum of missiles in Table 1 and Table 2 of "Design Basis Hurricane and Hurricane Missiles for Nuclear Power Plants", RG 1.221 (Reference 3.5-21) and "Technical Basis for Regulatory Guidance on Design-Basis Hurricane-Borne Missile Speeds for Nuclear Power Plants", NUREG/CR-7004 (Reference 3.5-22) with a design basis hurricane wind speed of 160 mph. DCD_02-03 S01

The spectrum of missiles is following: (1) a massive high-kinetic-energy missile that deforms on impact, (2) a rigid missile that tests penetration resistance, and (3) a small rigid missile of a size sufficient to pass through any opening in protective barriers.

Therefore, the spectrum of hurricane missiles is as follows:

- A 4,000 pound automobile, 16.4 ft by 6.6 ft by 4.3 ft, impacting the structure at normal incidence with a horizontal velocity of 135 ft/s or a vertical velocity of 85 ft/s. To accommodate site-specific conditions where grades within 0.5 miles of plant structures may have elevations higher than grade at the structures, this missile is considered to potentially impact SSCs at any azimuthal direction and at any elevation up to the lowest roof level of R/B surrounding PCCV, which is 98'-5" above grade, at the maximum hurricane missile velocity stated above. DCD_03.05.03-10 S01 DCD_02-03 S01

- A 6.625 inch diameter by 15 ft long schedule 40 pipe, weighing 287 pounds, impacting the structure end-on at normal incidence with a horizontal velocity of 102 ft/s or a vertical velocity of 85 ft/s.

- A 1 inch diameter solid steel sphere assumed to impinge upon barrier openings in the most damaging direction with a horizontal velocity of 89 ft/s or a vertical velocity of 85 ft/s.

Openings through the exterior walls of the seismic category I structures, and the location of equipment in the vicinity of such openings, are arranged so that a missile passing through the opening would not prevent the safe shutdown of the plant and would not result in an offsite release exceeding the limits defined in 10 CFR 100 (Reference 3.5-2). Otherwise, structural barriers are designed to resist ~~tornado~~ missiles in accordance with the design procedures discussed in Subsection 3.5.3. Tornado missiles and hurricane missiles are not postulated to ricochet or strike more than once at a target location. ~~Tornado m~~Missile protection is provided to resist the normal component of force delivered by the missile striking in any direction. Additional tornado loading design requirements are addressed in Subsections 3.3.2 and 3.8.4. Due to the robustness of the exterior wall design, all seismic category I structures ~~are capable of~~other than PCCV are designed to withstand~~ing~~ the impact of each identified tornado missile and hurricane missile at any elevation, including the potential impact of a 4,000 pound automobile ~~greater~~more than 30 feet above grade up to the lowest roof level of R/B surrounding PCCV, which elevation is 98'-5" above grade. DCD_02-03 S01 DCD_03.05.03-10 DCD_03.05.03-10 S01 DCD_02-03 S01 DCD_03.05.03-10 S01