# A Cooling Test of Improved CEDM Coil Stack Assembly

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## 1. Introduction

The main function of the CEDM(Control Element Drive Mechanism) coil stack assembly is to generate proper electro-magnetic field in order to draw, insert, or hold the control rod assembly at any position. During the plant normal operation, the CEDM coils are primarily heated by the motor housing that constitutes a reactor coolant pressure boundary, and additionally heated by the operating coil current. Under these conditions, therefore, it is very important to prevent thermal damages of the coils which can cause the control rod drop. In fact, there had been some cases of the control rod drop related to the thermal deterioration of the CEDM coils in the existing nuclear power plants.

As a part of APR plus(Advanced Power Reactor plus) development project, the CEDM coil as well as the CEDM has been studied to have less heat generation than present coil.

## 2. Design Improvements

There are 4 coils in a CEDM assembly, i.e., upper gripper(UG), upper lift(UL), lower gripper(LG), and lower lift(LL) coils. Each coil is enclosed by respective magnetic metal housing for being assembled together and providing the path of the electromagnetic flux. Among the 4 CEDM coils, the UG coil mostly generates electric heat during the plant operation since it is energized alone in the control rod HOLD mode. The newly developed CEDM UG coil has the following design features comparing to the existing UG coil.

A. Smaller clearance between the coil and the coil housing
B. Larger conductor size
C. Cooling fins on the outside of the coil housing

The above design features of A and B are related to each other. These design features had been determined through the electro-magnetic analysis such as an optimization study [1]. And to reduce the heat generation from the energized UG coil, the diameter of the conductor was increased and this change reduced the coil resistance significantly. By this change, most of the air gaps between the coil and the coil housing were reduced for better heat transfer. To maintain the electro-magnetic forces of the coils as those of the existing coils, the number of windings and the current values of the coils were maintained. The new design feature C above is such that the cooling fins are protruded radially from the surface of the coil housings in order to extend the heat transfer area for increasing the cooling efficiency of the coils.

## 3. Test Facility and Tests

The prototype coils and the coil housings were fabricated with the new design features and the product inspections were successfully carried out through measurements of resistance and inductance, insulation test, dielectric with-stand test, and dimensional checks.

For the cooling performance test, the prototype coil stack assembly was installed in a specifically designed test facility as shown in Fig. 1. The test facility consists of a blower, dampers, ducts, a motor housing mock-up, heaters, electric power supply, and some instruments such as an air flow meter, pressure gauges, RTDs, and thermo-couples.

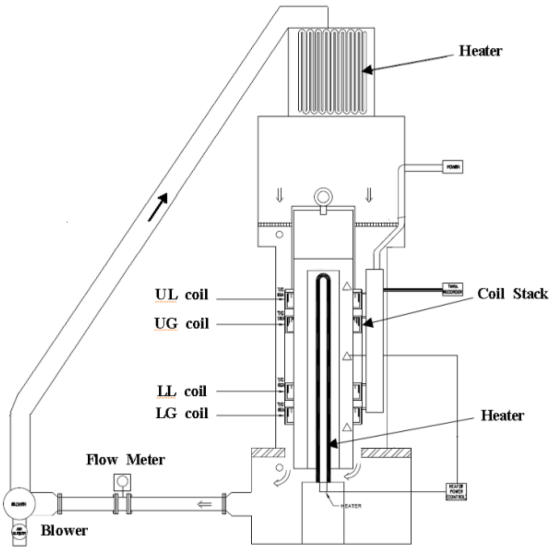


Fig. 1. Cooling performance test facility

The cooling performance tests were carried out in three conditions as follows;

1) Normal operating condition in the HOLD mode with a minimum cooling air flow of 15.3 ㎥/min at 49°C.
2) Complete loss of cooling air for 30 minutes in the HOLD mode
3) Complete loss of electric power and cooling air for 4 hours with the plant normal operating temperature

The coil temperature distribution was measured by an array of 6 or 12 fine wire thermocouples as shown in Fig. 2.

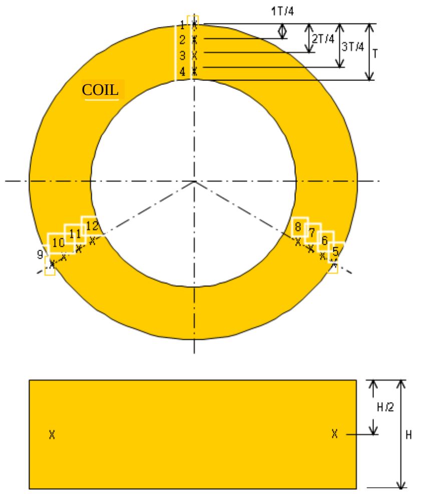


Fig. 2. Thermocouples(marked "x") in the UG coil as an example. Other coils each have 6 thermocouples(at the position numbers 1, 4, 5, 8, 9, and 12).

## 4. Test Results and Discussion

The highest temperature traces of the CEDM coils in the cooling performance tests are shown in Fig. 3. The highest temperature means the maximum temperature among 6 or 12 thermocouples in each coil.

First, in the CEDM normal operating conditions, the highest temperature of the UG coil was maintained at 189°C in the steady state which is lower than the allowable coil temperature of 204°C.

Second, in loss-of-cooling air conditions, the temperature of the UG coil rose rapidly up to 214°C in 30 minutes after shutting off the cooling air. And then after restoring the cooling air, the UG coil temperature was lowered again to about 190°C as the original steady state.

Third, in the conditions of complete loss of electric power and cooling air, the UG coil temperature was initially fallen down and then raised again up to 189°C at the steady state.

As shown in the third test results, the temperature of the UL and the UG coils rose to 185°C and The temperature traces of the 4 coils were converged on a narrow band after 4 hours. This temperature rise was purely due to the heat of the motor housing only. Therefore, the UG coil temperature rise by energizing and cooling effect by air cooling are almost balanced in the air flow 15.3 ㎥/min which is lower than the existing 22.7 ㎥/min with lower temperature than the maximum allowable temperature 204°C.

To inspect the integrity of the coils, the resistances and the inductances were measured before and after each test. In these inspections, there was no noticeable change in the values of the measurements and the final resistances and inductances of the coils were maintained in the range of normal values.

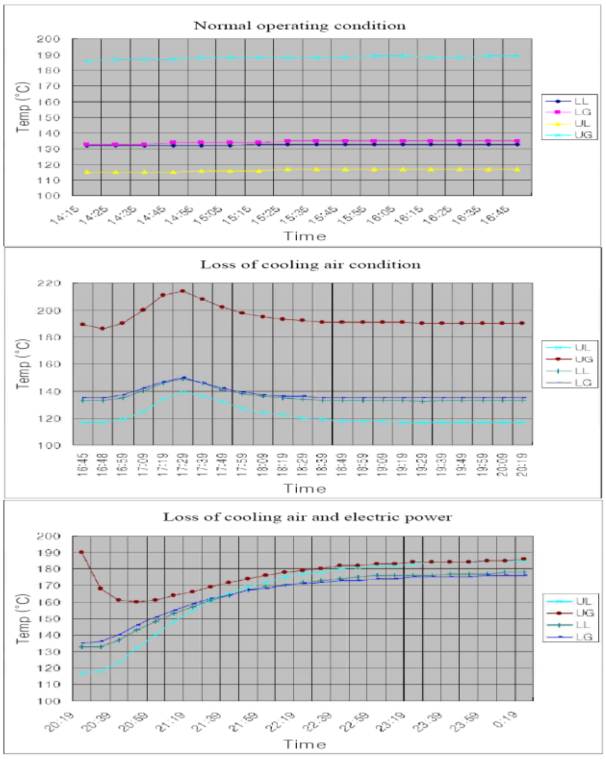


Fig. 3. Temperature traces of 4 CEDM coils

During the cooling performance tests, it was also confirmed that the highest coil temperature could be lowered up to 14°C by simply adding the cooling fins on the coil housing. In order to apply the cooling fins to the practical design, both the cooling effect and the adverse effect of increasing pressure loss should be properly balanced by optimization of the design variables of the cooling fins.

## 5. Conclusions

Through this experimental study, the cooling effects intended by three design improvements for the CEDM coils were analyzed. In conclusion, it was confirmed that the improved coils could withstand the severe conditions in normal and abnormal operating conditions. The cooling effect of the cooling fins on the coil housing was confirmed during the cooling performance tests. The design details of the developed coils and coil housings will be finally refined in the additional studies.

## REFERENCES

[1] Jin Seok Park, Myoung Goo Lee, Hyun Min Kim, In Young Kim. Optimization of the CEDM Coil and Housing, Proc. of the Korean Nuclear Society '08 Autumn Conference, 2008.