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Subject: **Report of Petrographic Observations**
Crystal River Containment Wall
Steam Generator Replacement Project
Crystal River Nuclear Generating Facility, Florida
MACTEC Project No. 6468-09-2535

Dear Mr.

MACTEC Engineering and Consulting, Inc. (MACTEC) is pleased to present this report of our petrographic observations performed on two concrete cores that were shipped to our laboratory under chain of custody. An additional core was received under chain of custody for limited observations. It is our understanding the two cores submitted for petrographic observations are from an area of the containment wall where a fracture was discovered running parallel to the surface at a depth of approximately 8 to 9 inches. We understand the core that was submitted for limited observations was from an area where the subject fracture had not occurred.

The cores submitted are as follows:

Core Number	Laboratory Number Assigned by MACTEC	Description of the Core
5	21269	From an area where the fracture had occurred
2	21270	From an area where the fracture had not occurred
7	21271	From an area where the fracture had occurred

Each core was photo documented as received and then saw cut longitudinally into halves. Each half was labeled with the same sample number and than A and B were added to designate the halves. As requested the B half for cores 21269 and 21270 were shipped to CTL Group in Skokie Illinois. The B half of core 21271 is being held for possible future use. The A half's of the cores were used for our analysis.
The purpose of our work was to perform a petrographic analysis of samples 21269A and 21271A and limited observations of sample 21270A. It is our understanding that you also require specific information

relative to the age of the fractured surfaces on samples 21269A and 21271A. Sample 21270A was used as a control sample that did not have a fractured surface.

Petrographic Observations

A Petrographic Analysis is a visual and microscopic analysis of cementitous materials performed by a qualified petrographer. Petrographic examinations are typically performed on polished sections or thin sections. Polished sections are generally cut sections that have been lapped (ground flat and smooth) and polished and are observed using reflected polarized light microscopes at magnifications of up to 80X. Thin sections are samples mounted to glass slides and ground to specific thicknesses (generally 20, 30, or 40 microns depending on the application) and observed using transmitted polarized light microscopes at magnifications of up to 600X.

A petrographic evaluation may be performed to identify and describe a specific item of interest such as the presence or extent of distress in concrete, or to provide a general characterization and measure of quality of the materials being evaluated. The petrographic evaluation of concrete examines the constituents of the concrete including coarse aggregates, fine aggregates, embedded items, hardened paste, and air void structure. The examination identifies cracking present in the concrete, indications of corrosion, extent of damage from external sources, aggregate reaction, chemical attack, sulfate attack, freeze thaw cracking, acid attack, and other mechanisms of deterioration. The petrographic examination can also estimate the water to cement ratio, look for indications of mineral additives and unhydrated cement particles in the paste, look for indications of bleed water and excess porosity in the concrete, look for indications of curing procedures used and methods of finishing, observe micro cracking present and other conditions within the concrete which might give information on the overall quality or the quality of any particular constituent material. Aggregate mineralogy, rock types, and mineral crystal structure can be identified when thin sections are viewed under a transmitted polarized light microscope.

TEST RESULTS AND OBSERVATIONS

PETROGRAPHIC OBSERVATIONS

The petrographic analysis was performed in general accordance with the applicable sections of ASTM C 856-04 Standard Practice for Petrographic Examination of Hardened Concrete. The results of our petrographic analysis are on the attached sheets, Summary of Petrographic Observations of Hardened Concrete. Photographs from our examination are attached. A summary of our observations and discussion are as follows.

Aggregate

The coarse aggregate generally consisted of a natural carbonate crushed rock with a maximum size of 3/4 inch. The rocks types observed included limestone, fossiliferous limestone, and a few particles of chert and/or limestone and chert. The particles were generally angular to sub-rounded in shape and fairly evenly distributed. The coarse aggregate appeared to comprise approximately 50% of the total aggregate quantity with the remaining fraction being fine aggregate.

On sample 21271, there were 4 coarse aggregate pieces on the cut surface of the core that retained moisture (and moisture in the surrounding paste) longer than other portions of the sample. These pieces are shown in Photographs 5, 6, 7, and 8. One of the pieces (Photograph 5 for core 21271) had a darkened rim. A thin section was prepared from the piece in photograph 7 and this piece contained microcrystalline quartz and radial silica and exhibited localized evidence of alkali silica reaction.

The fine aggregate was observed to be a natural siliceous sand consisting mostly of quartz. The particles were generally sub-angular to sub-rounded in shape and fairly evenly distributed.

Cement Paste

The cement paste was medium light gray (Reference colors from The Geological Society of America Rock-Color Chart, 1991). The paste appeared moderately hard and not easily scratched with a hardened steel point. The concrete appeared to have been placed at a moderately low water to cement ratio, possibly in the range of 0.4 to 0.5. Indication of placement at a high water to cement ratio such as significant bleed channels and water gain voids were not observed.

Air Voids, Voids, and Cracks

The concrete appeared to be air entrained and had a total air content estimated to be around 2 to 3%. The voids were generally small and spherical. Some air void clustering was observed around a few coarse aggregate particles. The air void distribution was moderately un-even and some small areas lacked air entrainment. There was limited mineral growth observed in some of the air voids. Calcium hydroxide was observed lining some air voids.

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- Location - Type	
Alteration: - Degree & Type - Reaction Products - Location - Identification	Not observed
Nature and Condition of Surface Treatments	There appeared to be white paint on the exterior surface of the core
Estimated water-cement ratio (based on visual observations only)	Appeared to have a moderately low w/c ratio possibly in the range of 0.4 to 0.5
Estimated cement content (based on visual observations only)	Appeared to have a moderately high cement content
PASTE:	
Color (GSA rock color chart 1991)	Medium light gray
Hardness	Appeared moderately hard when scratched with a hardened steel point
Porosity	Did not appear very porous. It took from 10 minutes to over 20 minutes to absorb 15 micro liter drops of water.
Carbonation	The outer ¼ to ½ inch of the exterior surface was carbonated. The fractured surface was not carbonated.
Residual un-hydrated Cement: - Distribution - Particle Size - Abundance - Composition	Some un-hydrated/partially hydrated cement particles were observed
Mineral Admixtures: - Size - Abundance - Identification	Fly-ash was not observed
Contamination: - Size - Abundance - Identification	Not observed

Equipment Used:

Cannon EOS Digital Rebel with 50mm macro lens and microscope adapters
AmScope 7X to 45X stereo zoom microscope (with and without polarized light)
Olympus BH-2 polarized light microscope
Zeiss Photomicroscope II polarized light microscope
Aven Digital Microscope
Starrett 6 inch rule SN 109000003

Note: No M&TE used is subject to calibration requirements.

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	particle.
Fractures	One end of the core contained a fractured surface. There were some other minor fractures on the end with the fractured surface. There were some fractures associated the chert particle discussed previously.
Embedded Items - Shape - Size - Location - Type	Not observed
Alteration: - Degree & Type - Reaction Products - Location - Identification	Not observed
Nature and Condition of Surface Treatments	There appeared to be white paint on the exterior surface of the core
Estimated water-cement ratio (based on visual observations only)	Appeared to have a moderately low w/c ratio possibly in the range of 0.4 to 0.5
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Contamination: - Size - Abundance - Identification	Not observed