



Balance-of-Plant Heat Exchanger and Condenser Tubing Eddy Current Inspection Best Practice Document Database

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Nathan Muthu
Technical Executive
Plant Support – NDE
nmuthu@epri.com

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BOP Heat Exchanger and Condenser Tubing Eddy Current Inspection Best Practice Document Database

Database Contents:

- 28 HX's with 62 downloadable ETSS and Final EC reports
- 6 Main Condensers with ETSS and Final EC reports
- 12 Metallurgical/Destructive Analysis Reports
- 2 downloadable eddy current inspection related calculators:
 - ❖ ASME flaw depth
 - ❖ Probe Fill-Factor and Frequency

ETSS = Evaluated Specification Technique Sheet (ETSS)

28 Heat Exchangers

Component Coolers	Emergency Diesel Generators	Low Pressure Feedwater Heaters	Reactor Cooling Pump Upper Motor Bearing Oil Cooler
Component Cooling Water	Flux Thimble Tubes	Low Pressure Injection System (LPI) Decay System	Reactor Pump Air Cooler
Condenser Heat Exchanger	High Pressure Coolant Injection (HPCI) Systems	Off Gas Recombiner Vent Cooler	Residual Heat Removal
Containment Spray	High Pressure Feedwater Heaters	Reactor Building Cooling Unit	Safety Shutdown Facility Diesel Lube Oil Cooler
Control Room AC Units	Isolation Condensers	Reactor Building Heat Exchanger	Seal Oil Cooler
Drywell Equipment Tank	Letdown and Access Letdown	Reactor Containment Fan Coolers	SSF HVAC Condenser
Emergency Diesel Generator Jacket Water and Lube Oil Cooler	Low Pressure Coolant Injection (LPCI) Systems	Reactor Cooling Pump Motor Air Cooler	Turbine Building Heat Exchanger

28 Heat Exchangers – 15 Different Common Material Type

Admiralty Brass
AL6XN
Arsenical Copper
304 Stainless Steel
316 Stainless Steel
321 Stainless Steel
AL6XN
Titanium
90/10 CuNi
70/30 CuNi
Inconel 600
Admiralty Brass with Low Fins
90/10 CuNi with External Fins
90/10 CuNi with Helical Wound Copper Fins
Copper with Integral Fins

62 downloadable Eddy Current Final Reports and Technique Sheets (ETSS)

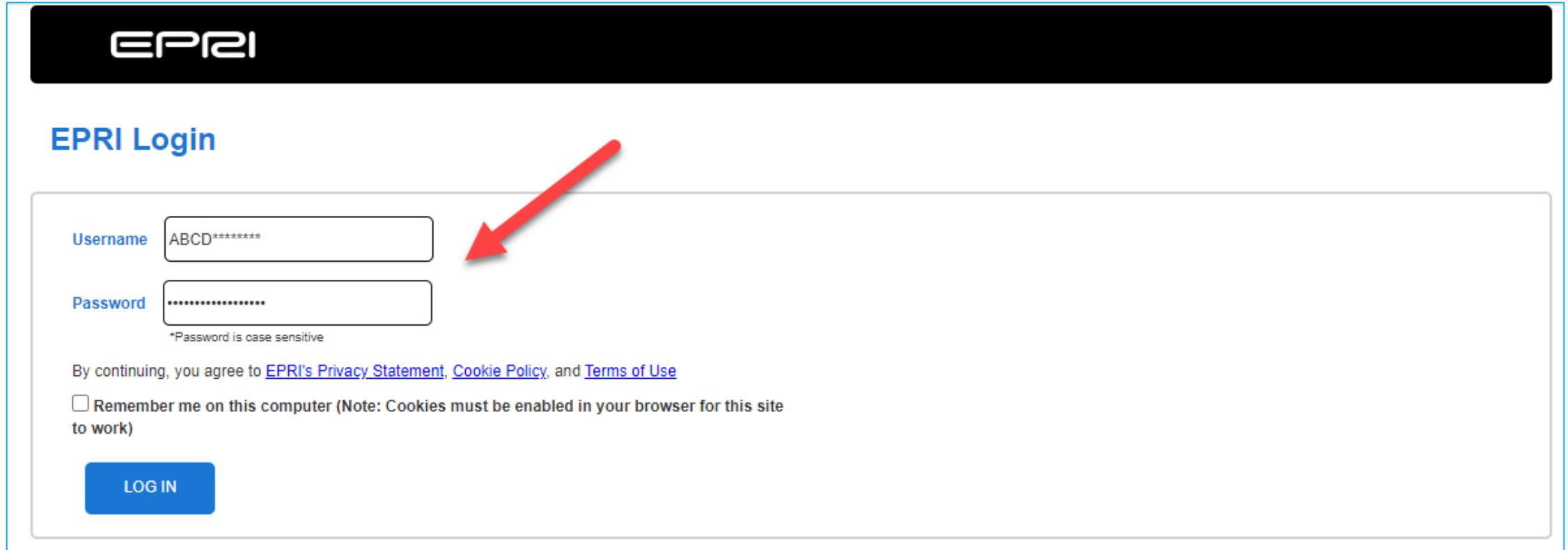
5 Condensers – 3 Different Common Material Type

90/10 CuNi
SeaCure
Titanium

5 downloadable Eddy Current Final Reports and Technique Sheets (ETSS)

Log In Information

- Log in with EPRI Credentials



A screenshot of the EPRI login interface. At the top is a black header with the white EPRI logo. Below the header, the text 'EPRI Login' is displayed in blue. The login form is enclosed in a light gray border and contains the following elements: a 'Username' label next to a text input field containing 'ABCD*****'; a 'Password' label next to a password input field showing masked characters; a red arrow pointing to the right side of the password field; a note '*Password is case sensitive' below the password field; a line of text stating 'By continuing, you agree to' followed by links for 'EPRI's Privacy Statement', 'Cookie Policy', and 'Terms of Use'; a checkbox labeled 'Remember me on this computer (Note: Cookies must be enabled in your browser for this site to work)'; and a blue 'LOG IN' button at the bottom left.

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Click on each Target/Topic

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Balance-of-Plant Heat Exchanger and Condenser Tubing Eddy Current Inspection Best Practice Document Database

Jeganathan Maruthamuthu

Welcome

Welcome to the EPRI Balance-of-Plant Heat Exchanger and Condenser Tubing Eddy Current Inspection Best Practice Document Database. This database contains a variety of inspection documents that EPRI members have used in the inspections of their safety and non-safety related heat exchangers and condensers. Supplemental information such as destructive, metallurgical, and root cause analysis reports of tubing degradation are also available. These valuable documents can heighten the engineer's awareness, knowledge, and understanding about tubing damage mechanisms seen in the industry and necessary actions to take to mitigate or eliminate similar tubing degradation issues.

Utilities and their stakeholders are encouraged to use these best practice inspection documents as reference to develop their own inspection techniques for optimal results based on their operating condition and damage mechanisms seen (historical and present). Using verbatim techniques, tools, and inspection parameters from this database are not recommended as they may lead to erroneous results.

Value

Access to shared industry knowledge will provide utility and their stakeholders with common eddy current tubing inspection techniques and practices that are being used in the industry. From these documents, utilities can meet their own inspection requirements by generating optimal inspection and data analysis techniques.

With optimal results, engineers can make informed and timely decisions about repair, replacement, and maintenance opportunities, successfully trend the eddy current data for flaw growth, and focus on high-risk zones for future inspections. This affords for improved asset management beyond normal life expectancy of the heat exchanger and importantly to evade disruptions to normal plant operation due to tube leaks.

Use in Conjunction with the Following EPRI Reports

Users are encouraged to review **EPRI product # 3002023702 titled, BOP Heat Exchanger and Condenser Tubing Degradation Database**. This database affords the user to understand other utilities tube design, their operating conditions and inspection frequency, tube inspection and degradation results, tube repair approaches, tube leak management, tube leak consequences, and utility concerns. Some eddy current reports and inspection technique sheets are also provided for that specific heat exchanger or condenser. Members may also review and download these documents for use.

Another supportive report to this database is product ID #: **3002013154 titled, Balance-of-Plant (BOP) Electromagnetic Nondestructive Evaluation Guide for Engineers: Best Practices to Successfully Execute an Eddy Current Inspection Campaign**. This report provides the necessary information and tools to support the engineer throughout the various stages of performing eddy current inspections of heat exchangers and condenser tubing including, manufacturing, bundle assembly, pre-service (baseline inspections), and in-service inspections. The topics are supported with a series of checklists that engineers may download, modify, and use throughout the inspection processes. The aim is to support a thorough understanding of eddy current inspection processes, and thereby increase the confidence level of engineers, aiding them in their interactions with their inspection vendors and helping them to take ownership and make informed decisions of their heat exchanger and condensers.

Request

Contact Nathan Muthu, nmuthu@epri.com or Matt Wolf, mawolf@epri.com if errors are found in the presented documents and calculators, if updated inspection documents to supersede existing documents are available, or if you wish to provide your inspection documents to be included in the database.

Nuclear Database Agreement

Balance-of-Plant Heat Exchanger and Condenser Tubing Eddy Current Inspection Best Practice Document Database 1.0
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Heat Exchanger Page

- 1) Select Component
- 2) Select Material
- 3) Download Documents for Review

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Jeganathan Maruthamuthu

Heat Exchangers

Several heat exchangers are listed under the "Select Component" pull down menu. First, select the heat exchanger type, then from the "Select Material" pull down menu, select the tubing material of interest.

An active link to download available documents (ETSS based on tubing material and dimension and final reports) will be displayed under the "Component Documents". Click on the document to review or download. From this information, you may generate your ETSS based on your own heat exchanger historical performance, past and present tubing degradation types reported, water chemistry, and operating conditions for optimal inspection techniques and results. Remember not to use verbatim techniques from the downloaded documents in your inspections.

If the technique you developed and used in your inspection provided optimal results, please consider sharing your operating experience (OE) with the rest of the industry. You may do so by providing the ETSS, metallurgical and destructive analysis results, and final report to the EPRI project managers Nathan Muthu, nmuthu@epri.com or Matt Wolf, mawolf@epri.com for inclusion in the next database update. Conversely, if you find any errors in the existing documents, please contact the project managers immediately.

Select Component:

Low Pressure Feedwater Heaters

Select Material:

304 Stainless Steel

Component Documents:

Filename	CreatedDate
14A FWH Final Report_1RE21_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024
14A FWH Final Report_1RE19_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024
14B FWH Final Report_1RE22_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024
14B FWH Final Report_1RE16_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024
14B FWH Final Report_1RE20_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024
14B FWH Final Report_1RE24_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024
2018-09 FPR23-33E-3A_Final Report_0.625 x 0.035 (15.87mm x 0.89mm)_Constellation.pdf	02/16/2024
2022-09 J1R25-33E-3A_Final Report_0.625 x 0.035 (15.87mm x 0.89mm)_Constellation.pdf	02/16/2024
2023-02 CC2R25_Final Report_0.625 x 0.035 (15.87mm x 0.89mm)_Constellation.pdf	02/16/2024
24A FWH Final Report_2RE17_0.625 x 0.035 (15.87mm x 0.89mm).pdf	02/16/2024

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Condenser Page

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Main Condensers

Several condenser tubing material types are provided under the 'Select Material' pull down menu. Select the tubing material of interest to you. An active link to download the available documents will be displayed under the 'Component Documents'. Click on the document to review or download. From this information, you may generate your own ETSS based on your own condenser historical performance, past and present tubing degradation types, water chemistry, and operating conditions for optimal inspection techniques and results. Remember not to use verbatim techniques from the downloaded documents in your inspections.

If the technique you developed and used in your inspection provided optimal results, please consider sharing the operating experience (OE) with the rest of the industry. You may do so by providing the ETSS and final report to EPRI by contacting Nathan Muthu, nmuthu@epri.com or Matt Wolf, mawolf@epri.com for including in the database.

Select Material:

Titanium

Component Documents:

Filename	CreatedDate
Final Report_0.750 x 0.028 (19.05mm x 0.71mm)_South Texas Project.pdf	11/10/2023
Final Report_0.875 x 0.049 and 0.028 (22.2mm x 1.24mm and 0.71mm)_Consteallation.pdf	11/10/2023
Final Report_1.250 x 0.028 (31.7mm x 0.71mm)_Titanium Constellation.pdf	11/10/2023

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Metallurgical / Destructive Analysis Reports Page

1) Download Document for Review of Flaw Damage Forensics

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Analysis Reports

EPRI utility members have provided examples of metallurgical and destructive analysis reports that are included in this section. Some reports may be several years old, but lessons learned from all reports provide the necessary information for plants to understand the root causes of tube leaks and other damage forms seen in Balance-of-Plant heat exchangers and condensers. This information is valuable as it affords the utility to make informed decisions to prevent future issues.

Added value to metallurgical and destructive analysis of extracted tube specimens include the ability to assess the robustness of the current eddy current data analysis techniques and to fabricate additional calibration standards from defect free sections of the extracted tubes. Because the flaw morphology is well understood, representative flaws can be fabricated to improve the data evaluation examination technique specification sheet (ETSS) and flaw depth sizing results.

Filename

Cooling Water Corrosion Assessment-NMP NPP.pdf

Failure Analysis Report of Main Condenser Tubes-NMP NPP.pdf

Met Evalauton on Turbine Lube Oil Cooler Tubes-Dresden NPP.pdf

Met Evaluation on Condenser Tubes-Braidwood NPP.pdf

Met Evaluation on Condenser Tubes-NMP NPP.pdf

Met Evaluation on DG Jacket Water HX Tubes.pdf

Met Evaluation on ID Pit Evaluation from CCWHX Tube-Braidwood NPP.pdf

Met Evaluation on Isolation Cond HX Tube-Dresden NPP.pdf

Met Evaluation on Main Feedwater Pump Lube Oil Cooler Tubes-Ginna NPP.pdf

Met Evaluation on TBCCW HX Tubes-Fermi NPP.pdf

Met Evaluation on Turbine Lube Oil Cooler Tubes-Ginna NPP.pdf

Met Evalauton on EHC Fluid HX Tubes-Dresden NPP.pdf

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ASME Calibration Standard Flaw Depth Calculator

1) Download Spreadsheet to your Desktop and Use

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ASME Calibration Standard & User Defined Flaw Depth Calculator

ASME Calibration Standard Flaw Depth Calculator

Note: Enter in Inches or Millimeters. Not both.

	In Inches	In Millimeters	Notes
Enter Tube OD Here	0.625		Intentionally left blank
Enter Tube Wall Thickness Here	0.028		
100% Through Wall Hole Diameter	0.052		* Up to 0.750-inch (19.05 mm) OD, 0.052-inch (1.32 mm) diameter. ** Greater than 0.750-inch (19.05 mm) OD, 0.067-inch (1.70 mm) diameter.

ASME Type Standard Flaw Depths

Desired Flaw Depth	Approximate Fabricated Depth	Fabricated Depth Measurement in Inches (rounded)
Through Wall Hole	100%	Through Wall Hole
80% ODFBH	78.57%	0.022
60% ODFBH	60.71%	0.017
40% ODFBH	39.29%	0.011
20% ODFBH	21.43%	0.006
20% 360 Deg OD Groove	21.43%	0.006
10% 360 Deg ID Groove	10.71%	0.003

Additional Depth Information Entered by User

(can be used in calculating flaw depths for other calibration standards)

User Enter Desired Depth in %	Fabricated Depth Measurement in Inches
20	0.006
30	0.008
45	0.013
65	0.018
85	0.024

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Probe Fill-Factor and Frequency Calculator

1) Download Spreadsheet to your Desktop and Use

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Frequency and Probe Fill-Factor Calculator

This downloadable Excel spreadsheet can be saved to your desktop. It allows you to calculate the probe fill factor, inspection frequencies, and standard depths of penetration. Make sure to enter information in inches or millimeters, not both.

Tube and Probe Fill-Factor Information

Enter in Inches or Millimeters. Not both

Enter Tube Outside Diameter

In InchesIn Millimeters

19.05

Enter Tube Wall Thickness

In InchesIn Millimeters

1.24

Tube ID

In InchesIn Millimeters

0.65216.570

Probe OD, Subtract 0.040" (1.0mm) from tube ID

In InchesIn Millimeters

0.61215.554

Probe Fill-Factor in %

In InchesIn Millimeters

88.1%

Note

Probe diameter is normally manufactured to the nearest 0.010-inch (0.254 mm)

Enter the new rounded probe diameter size either in inches or millimeters (not both) to find out the probe fill-factor

Enter Probe OD rounded to the nearest 0.010" (0.254 mm) Diameter

In InchesIn Millimeters

0.620

Probe Fill Factor in %

In InchesIn Millimeters

90.3%

Frequency and Standard Depth of Penetration Calculation

Enter Material ID from Table OR Enter Custom Resistivity Value. Not both

Enter Tube Material ID # from List

Resistivity in micro-ohms-cm

% IACS

Custom Resistivity Value in micro-ohms-cm

One Depth of Penetration

Number of Standard Depths

Frequency in kHzInchesMillimeters

1 Standard Depth/Wall Thickness

Optimum Frequency

F90 Detection Frequency

Enter your Own Frequency

Material ID #UNSMaterialResistivity μΩ-cm% IACS

1C44300Admiralty Brass7.1824.01

2Aluminum (99.9%)2.6664.82

3A92024Aluminum 2024-T45.2033.16

4A96061Aluminum 6061-T64.0742.36

5A97075Aluminum 7075-T65.3931.99

6C60800Aluminum Bronze12.3213.99

7S44735AL 29-4C®72.002.39

8N08366AL-6X94.761.82

9N08367AL6XN®89.001.94

10S32101Alloy 210180.002.16

11S32205Alloy 220580.002.16

12S32304Alloy 230480.002.16

13S32750Alloy 250780.002.16

14S32550Alloy 25582.102.10

15S32760Alloy 450180.002.16

16N08904Alloy 904L95.201.81

17Austenitic Stainless Steel73.002.36

18C23000Brass, red4.6637.00

19C27000Brass, yellow6.3926.98

20C22000Bronze (annealed)3.9243.98

21Carbon Steel (0.65% C)18.009.58

22Carbon Steel (1% C)20.008.62

23Carbon Steel, Generic16.0010.78

24C11000Copper (Electrolytic Tough Pitch)1.71100.82

25C12200Copper, deoxidized (annealed)2.0384.93

26Copper, IACS1.72100.24

27Copper, Pure1.67103.24

28C71500Copper/Nickel 70/3038.314.50

29C71000Copper/Nickel 80/2026.206.58

30C70600Copper/Nickel 90/1017.719.74

46N06617Inconel® Alloy 617122.001.41

47N06625Inconel® Alloy 625129.001.34

48N07718Inconel® Alloy 718125.001.38

49Ingot Iron (99.9% iron)11.0515.60

50Iron9.5818.00

51Lead20.538.40

52Molybdenum5.2033.16

53N04400Monel 40048.163.58

54C28000Muntz metal (annealed)6.1627.99

55NIMONIC® Alloy 75109.001.58

56NIMONIC® Alloy 80A124.001.39

57S20910Nitronic® 50 (XM-19)82.002.10

58Platinum10.6416.20

59SEA-CURE®66.002.61

60Silver, pure1.64105.13

61S40300Stainless Alloy 40357.003.02

62S41000Stainless Alloy 41056.003.08

63S42000Stainless Alloy 42056.003.08

64S20100Stainless, Type 20169.002.50

65S30100Stainless, Type 30172.002.39

66S30200Stainless, Type 30272.002.39

67S30400Stainless, Type 30468.972.50

68S30500Stainless, Type 30572.002.39

69S30900Stainless, Type 30978.002.21

70S31000Stainless, Type 31078.002.21

71S31600Stainless, Type 31674.962.30

72S31700Stainless, Type 31774.002.33

73S31703Stainless, Type 317L79.002.18

74S32100Stainless, Type 32172.002.39

75S34700Stainless, Type 34773.002.36

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2024 SOFTWARE MANUAL

Balance-of-Plant Heat Exchanger and Condenser Tubing Eddy Current Inspection Best Practice Document Database

Version 1.0, APRIL 2024

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Continued Reach Out Will be Done to Build This Database

- This is a living database.
 - Updated documents that can supersede present documents (Improvements to existing techniques).
 - If an error with the present documents are identified.

Next Update to Database

- Tentative plan is to reach out to the industry in 18 months (September 2025) and release version 2 in September 2026 (~2 ½ year update cycle).



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