ENCLOSURE 2

MFN 05-079

NEDE-33179P
Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring, Licensing Topical Report

Non-Proprietary Version

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to MFN 05-079, which has the proprietary information removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]]

GE Nuclear Energy

NEDO-33197
Revision 0
eDRF 0000-0041-9907
Class I
September 2005

Licensing Topical Report

Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring

C. L. Martin

NON PROPRIETARY NOTICE

This is a non proprietary version of the document NEDE-33197P, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The information contained in this document is furnished for the purpose of obtaining NRC approval for the use of a Gamma Thermometer System for LPRM calibration and power distribution monitoring. The only undertakings of General Electric Company respecting information in this document are contained in the contracts between General Electric Company and the participating utilities in effect at the time this report is issued, and nothing contained in this document shall be construed as changing those contracts. The use of this information by anyone other than that for which it is intended is not authorized; and with respect to any unauthorized use, General Electric Company makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

CONTENTS

TABLES

ABSTRACT

A Gamma Thermometer (GT) System for LPRM calibration and power shape monitoring is described. The major hardware and software components are identified and a practical GT response model is developed. Three in-plant tests at Limerick 2 (Exelon), Tokai 2 (JAPC) and Kashiwazaki-Kariwa 5 are provided to qualify the sensors and assess accuracy. An adaptive core monitoring simulation is used to assess the impact of the GT System on core monitoring. Lastly, an uncertainty analysis is performed to quantify the impact on bundle power uncertainty and on thermal limits.

ACKNOWLEDGEMENTS

Numerous individuals deserve credit in one way or another for the design, development and testing of GT technology. The author gratefully acknowledges the many and varied contributions of the following and apologizes to anyone that is inadvertently left off:

GE Nuclear Energy, GE Reuter-Stokes and their contractors including: T. Leong, B. Bohn, C. Sawyer, Raghu Raghavan, William F. Splichal, F. Chao, J. Kirtland, A. Wirth, J. P. Doyle, D. R. O'Connor, F. Glesius, W. White, M. Elder and G. Deaver.

Exelon (formerly PECO Energy Company) and its staff including (but not limited to): Kevin Ballard, S. Auve, F. Buckley, T. Bell, C. Capriotti, B. Eaton and J. Sealy.

Japan Atomic Power Company (JAPC): Tomimori, J. Shimizu

Toshiba Corporation: T. Itoh, K. Hirukawa, Y. Goto, S. Sakurai, T. Naka

ACRONYMS AND ABBREVIATIONS

Term	Definition
BOC	Beginning of cycle
BWR	Boiling Water Reactor
CFR	Code of Federal Regulations
CPR	Critical Power Ratio
DACS	Data Acquisition and Calibration System
DAS	Data Acquisition System
DLC	Data Logging Computer
EOC	End Of Cycle
ESBWR	Economic Simplified Boiling Water Reactor
GETAB	General Electric Thermal Analysis Basis
GT	Gamma Thermometer
GTC	Gamma Thermometer Control Unit
GTM	Gamma Thermometer Monitoring Unit
HPS	Heater Power Supply
HSU	Heater Switching Unit
LPRM	Local Power Range Monitor
LTR	Licensing Topical Report
MCPR	Minimum Critical Power Ratio
MLHGR	Maximum Linear Heat Generation Rate
NA	Not Applicable
NRC	Nuclear Regulatory Commission
O&M	Operation and Maintenance
PANAC11	PANACEA, GE BWR Core Simulator
TIP	Traversing In-core Probe

1. INTRODUCTION

A Gamma Thermometers (GT) is a simple, solid-state device for measuring the thermal effects of intense gamma ray fields. GTs show great promise in simplifying BWR in-core instrumentation for future plants by providing an economical alternative to the Traversing In-core Probe (TIP) system.

The TIP system, which may be based on either gamma or neutron sensitive detectors, provides measurements for calibrating the Local Power Range Monitors (LPRMs) and for adapting (improving) the power distribution from the Core Monitoring System. Although TIP systems fulfill their intended purpose quite satisfactorily, their Operating and Maintenance (O&M) costs are high. This is due to the many moving parts in the system, the complex under-vessel tubing which must often be disconnected during maintenance, the radiation dose to maintenance personnel in the neighborhood of the stored TIP probes and other problems. A GT system, on the other hand, fulfills the functions of the TIP system, yet it has no moving parts, no under vessel tubing, no radiation problems and is expected to be very reliable.

A Gamma Thermometer based instrument system has been selected in place of a TIP system for the Economic Simplified Boiling Water Reactor (ESBWR) and is likely to be incorporated in all future BWR designs.

1.1 Purpose

The purpose of this document is to supply regulators (and others) with sufficient information to understand the technical features of the GT system and to confirm the suitability of the GT system for LPRM calibration and power distribution monitoring.

1.2 Scope of Review

GE requests that the NRC approve the GT system for calibration of LPRMs and for supplying power shape information to the core monitoring system.

1.3 Description of a Gamma Thermometer

A Gamma Thermometer is a device used for measuring the gamma flux in a nuclear reactor. A section of a typical GT is shown in Figure 1-1. It consists of a stainless steel rod that has short sections of its length thermally insulated from the reactor coolant. The insulation, normally a chamber of Argon gas, allows the temperature to rise in the insulated section in response to gamma energy deposition. A two-junction thermocouple measures the temperature difference between the insulated and non-insulated sections of the rod. The thermocouple reading is thus related in a straightforward way to the gamma flux. When properly adjusted for the number and spectrum of the gamma rays produced from fission and neutron capture, the fission density in the

surrounding fuel can be inferred from the gamma flux and therefore indirectly from the thermocouple reading.

An ohmic heater wire is placed in the center of the GT rod to provide a means of calibration of the thermometers, which are expected to decline slowly in sensitivity during the first few months of operation. The calibration procedure consists of passing a known current through the heater wire and noting the increase in thermocouple response. When properly calibrated in this manner, the GT rod can perform both of the normal functions of a Traversing In-core Probe (TIP): calibration of the LPRMs and providing power shape information to the plant monitoring system.

A diagram of a GT assembly that is designed to replace a standard LPRM/TIP assembly is shown in Figure 1-2. The GT assembly consists of a GT rod with several GT sensors and the normal compliment of four LPRMs.

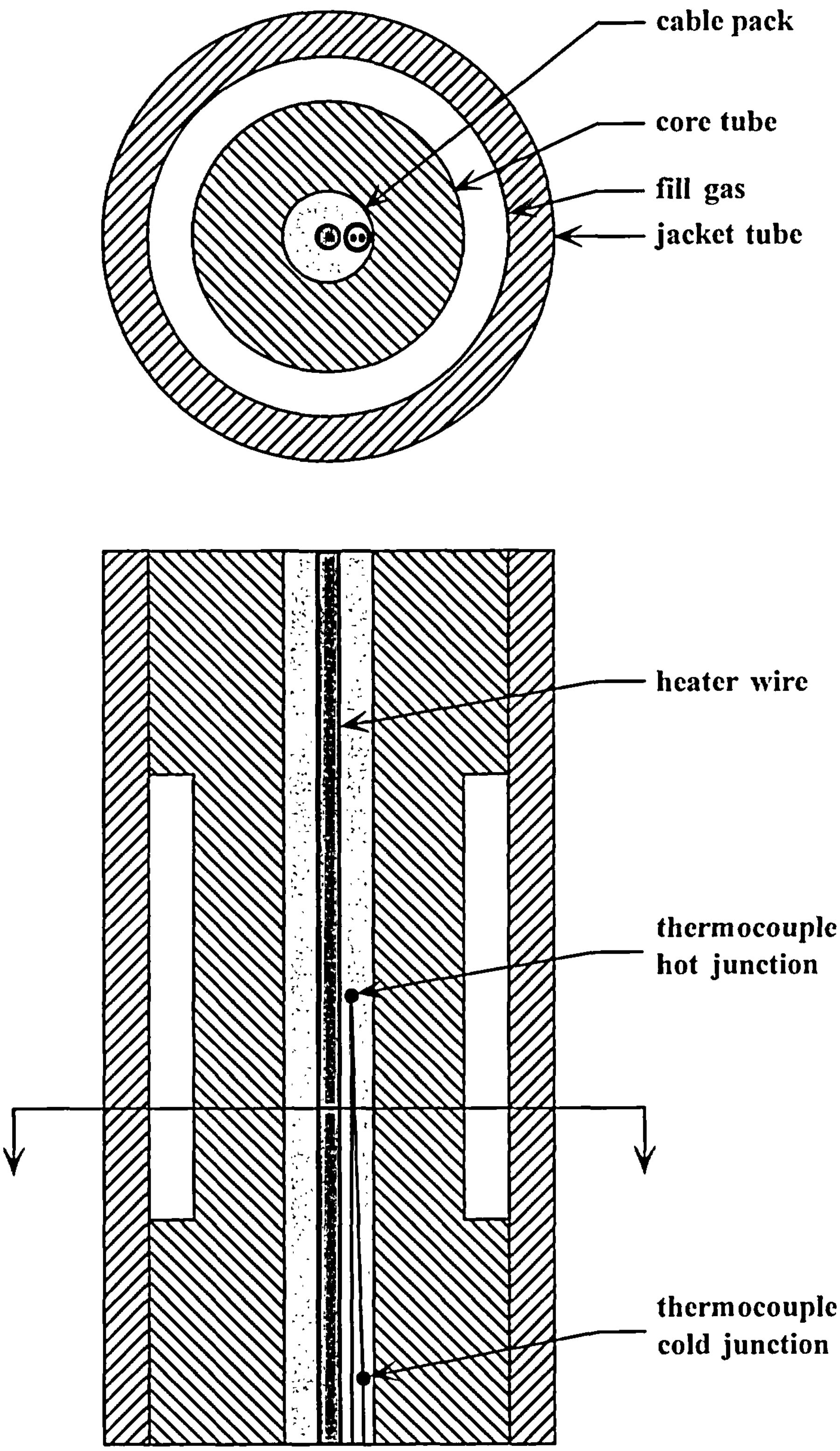


Figure 1-1, Cross Section of a Gamma Thermometer

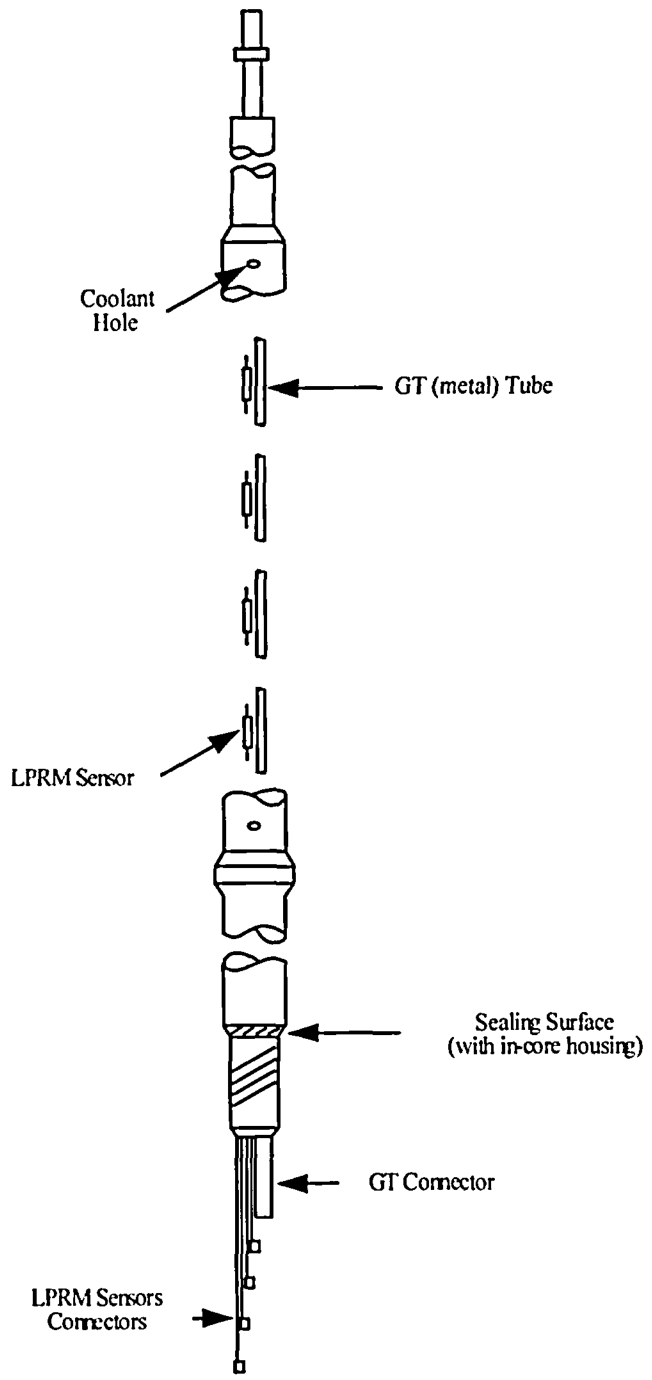


Figure 1-2, LPRM/GT Assembly

1.4 Advantages of the GT System

The GT System has many advantages over the TIP system:

- No moving parts to wear out
- Reduced occupation exposure
- Reduced rad waste
- No open tube penetrations to the containment
- Reduced space requirements in the reactor building
- More frequent LPRM calibrations
- More frequent adaptive monitoring calculations

2. GT SYSTEM REQUIREMENTS

2.1 Design Requirements

There are two general functional requirements for the GT system:

- Provide accurate information for the calibration of the LPRMs. Such calibration must occur at least every 30 days, although it is expected that it will occur much more frequently, even multiple times in a single day.

- Provide accurate axial shape information for use by the core monitoring system. This information should be available at any time, even during slow transients (Xenon, flow, etc.) as long as the time frame is substantially longer than the thermal time constant of the GT sensors.

2.2 Codes and Standards

1) LPRM/GT assemblies must be designed, manufactured and tested according to all applicable U.S. Codes and Standards.

When manufactured for use in a nation other than the U.S., LPRM/GT assemblies must also comply with that nation's codes and standards.

3. GT SYSTEM DEFINITION

3.1 Hardware Components

The hardware configuration for a typical GT core monitoring system is shown in **Figure 3-1**. The hardware includes new components such as the LPRM/GT assemblies, the Data Acquisition System (DAS) and the Heater Power Supplies (HPS). A listing of the new components is provided in Table 3-1. Also listed is the number of each type of component that is required for a complete system.

Table 3-1, GT Core Monitoring Component List

Component Name	Number (Typical)
LPRM/GT Assembly	64
GT Sensors per Assembly	4
Data Acquisition System Cabinet	2
Heater Power Supplies	8
GT Control Cabinet (including Work-Station)	1

3.1.1 LPRM/GT Assembly

The LPRM/GT assemblies are similar to standard LPRM assemblies: each has four LPRMs and is designed to meet all of the normal requirements. In the ESBWR configuration, each assembly has four GTs. In other designs, up to nine GTs are possible. In the nine GT configuration, the GTs are positioned as follows: one adjacent to each LPRM, one midway between each pair of LPRMs, one midway between the bottom of the core and the lowest LPRM and finally, one midway between the highest LPRM and the top of the core.

There are many requirements that the GT sensors must meet. For example, the range in gamma heating rate should be 0.0 to 2.4 W/g for a typical BWR. In addition, the GT sensitivity at beginning of life at operating temperature (286°C) should be 1.5 mV-g/W ±20%. (For a complete list of requirements see in Table 9-1.)

The environmental design ratings, including the operating temperature, neutron flux, gamma dose rate and seismic loadings are the same as for standard LPRM assemblies. The GT sensors are designed to last at least as long as the LPRMs.

For demonstration systems only, a calibration tube is included in the assembly so that the TIP system remains fully operational. This permits a direct comparison between the TIP and GT systems.

3.1.2 Data Acquisition System

The main function of the Data Acquisition System (DAS) is to transform the GT readings from an analog signal to a digital value. The environmental design ratings are similar to other electronics in the reactor building. In additional, the DAS system performs digital filtration to remove noise as well as digital compensation to account for delayed gammas (see section 4.5 for a discussion of delayed gamma compensation).

3.1.3 Heater Power Supply

The purpose of the Heater Power Supply (HPS) is to provide a DC electrical current to the internal GT heaters during calibration. The current must be of sufficient magnitude to allow an accurate calibration of each GT sensor. The HPS, for economic reasons, is multiplexed such that several GT assemblies are serviced sequentially by a single power supply. In Figure 3-1, the HPS are included in the DAS cabinets.

3.1.4 GT Control Cabinet

The GT Control Cabinet contains an Engineering Work-Station (EWS) that is the principal interface to the GT system. It provides a manual way of initiating the GT calibration and in addition, provides color graphic displays of all useful output: GT readings, GT sensitivities and others.

The EWS communicates with the other units including the DAS and ATLM cabinets through a fiber optic link.

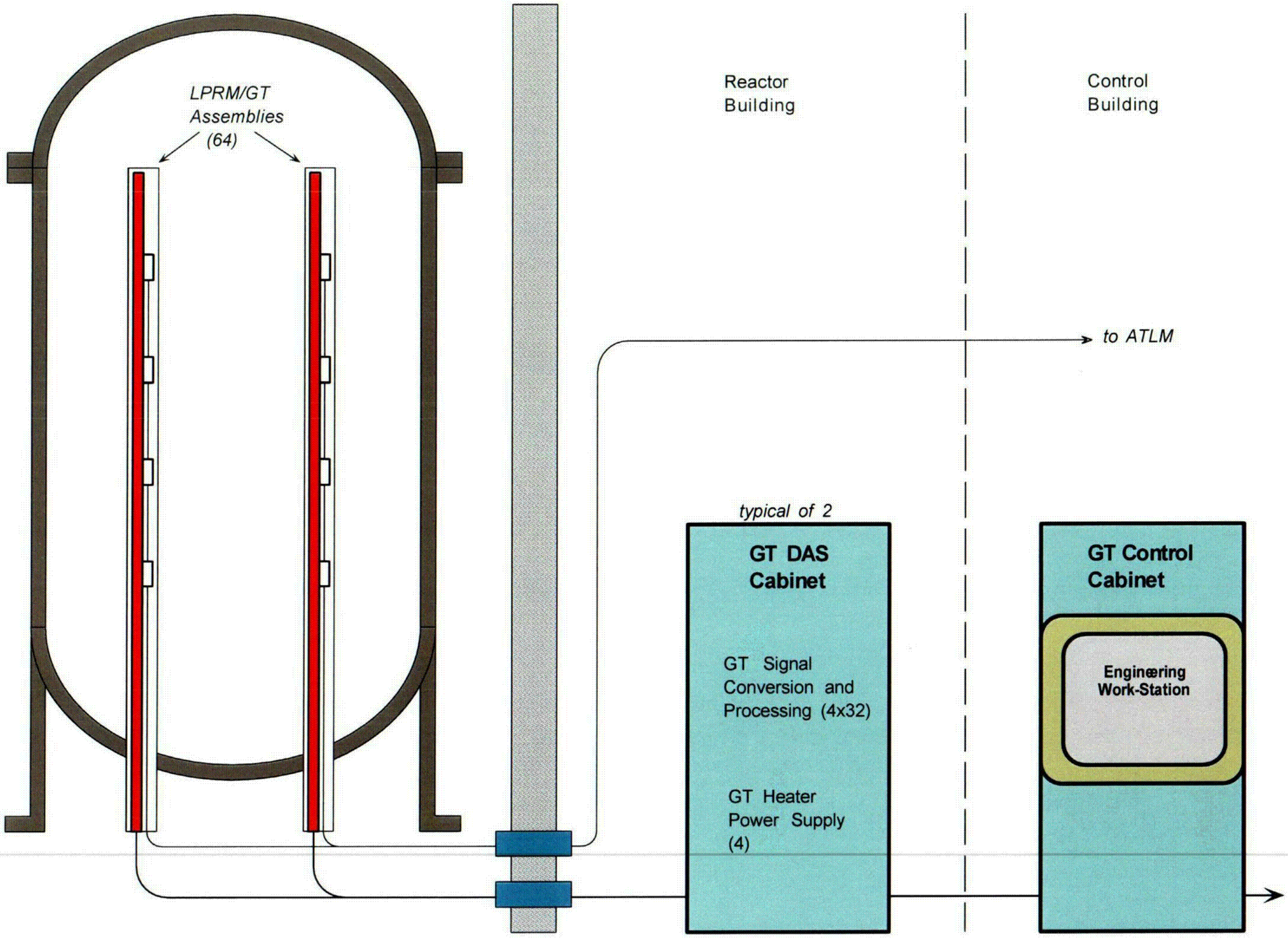


Figure 3-1, GT Core Monitoring System Configuration

C01

3.2 Software Components

[[

]]

3.2.1 GT Monitor Module

[[

]]

3.2.2 GT Calibration Module

[[

]]

3.2.3 3D Simulator

[[

]]

3.2.4 User Interface

[[

]]

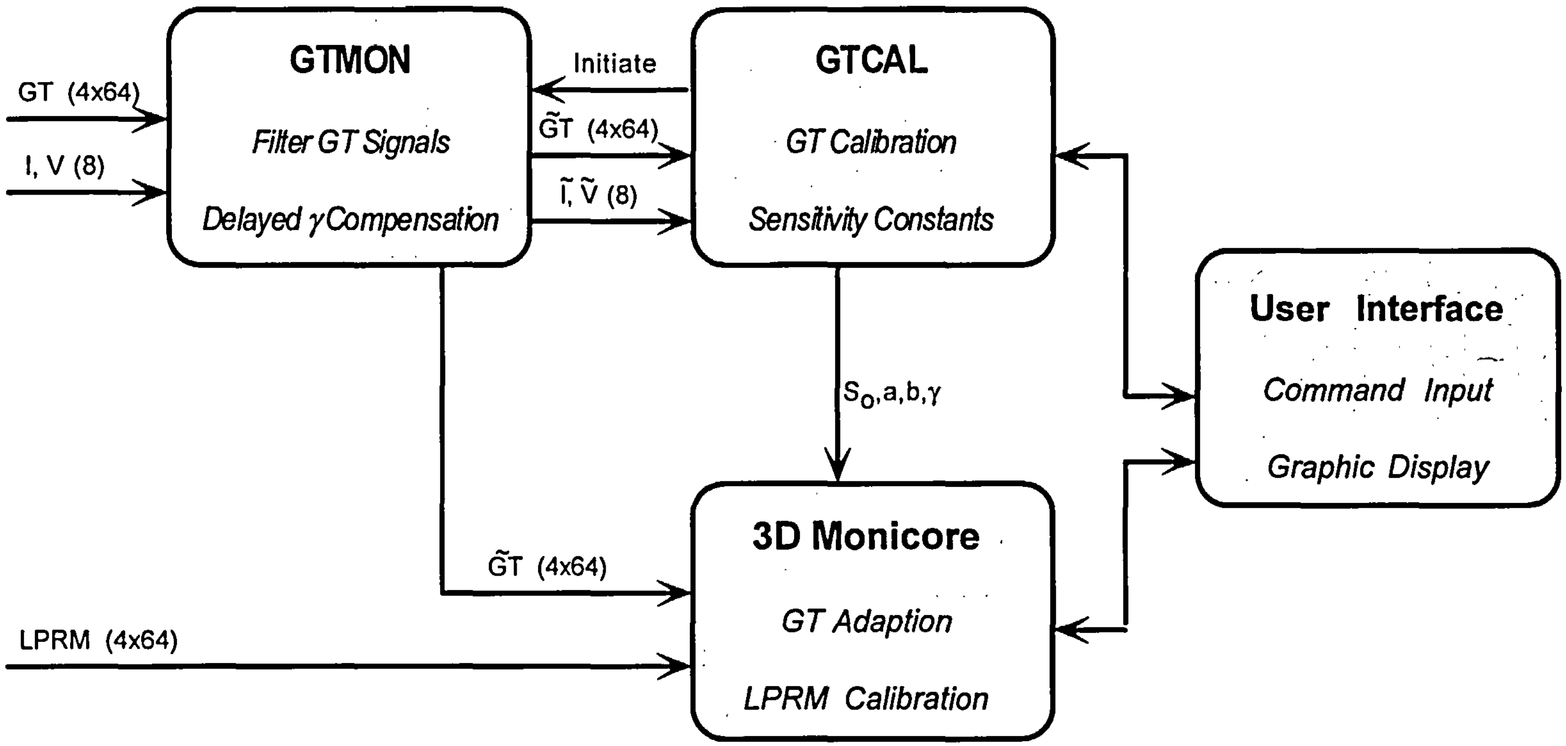


Figure 3-2, GT Core Monitoring Software Diagram

4. GT RESPONSE MODEL

4.1 GT Response to Gamma Energy Deposition

[[

]]

4.2 GT Factory Calibration

[[

]]

[[

]]

[[

]]

4.3 GT In-Plant Calibration

[[

]]

4.4 Sensitivity Decrease Model

[[

]]

4.5 Delayed Gamma Compensation

[[

]]

[[

]]

[[

]]

The following table shows the values of the constants used in this report:

Table 4-1, Constants for Delayed Gamma Compensation

Mode	a_n	τ_n (seconds)
0	0.76519	1.83800E+01*
1	0.04129	8.48320E+00
2	0.03725	2.90994E+01
3	0.04250	8.50196E+01
4	0.02054	2.77277E+02
5	0.01488	7.16178E+02
6	0.02867	1.59724E+03
7	0.02294	5.28430E+03
8	0.01314	1.81574E+04
9	0.00802	4.76849E+04
10	0.00559	1.00060E+05

[[

]]

* Average thermal time constant (Joule method) of the detectors in the Joint Study

5. GT SYSTEM FUNCTIONS

The two functions of the GT System, LPRM calibration and power shape monitoring, are briefly described in the following sections.

5.1 LPRM Calibration

[[

]]

5.2 Core Monitoring with GT Adaption

[[

]]

6. FACTORY TESTS

[[
]]

6.1 GT Factory Tests

[[

]]

6.2 LPRM/GT Assembly Factory Tests

[[

]]

7. IN-PLANT QUALIFICATION TESTS

There have been three in-plant tests of GT sensors in BWRs thus far. The first test was at Limerick 2 and lasted for two cycles, a total of four years. The second test, which was at Tokai 2, lasted for a single cycle of one year duration. These two tests will be described in detail in sections 7.1 and 7.2 , respectively. Published data from a third test at Kashiwazaki-Kariwa 5 are available in the open media and are summarized in section 7.3.

7.1 Limerick 2 In-Plant Test

The Limerick 2 plant, operated by Exelon (formerly PECO Energy) is an 1100 MWe BWR4. It has 764 bundles arranged in a "C" lattice configuration (equal water gaps). It has a gamma sensitive TIP system with a total of 43 calibration tubes and associated LPRM strings.

7.1.1 Test Plan

[[

]]

[1] [[

]]

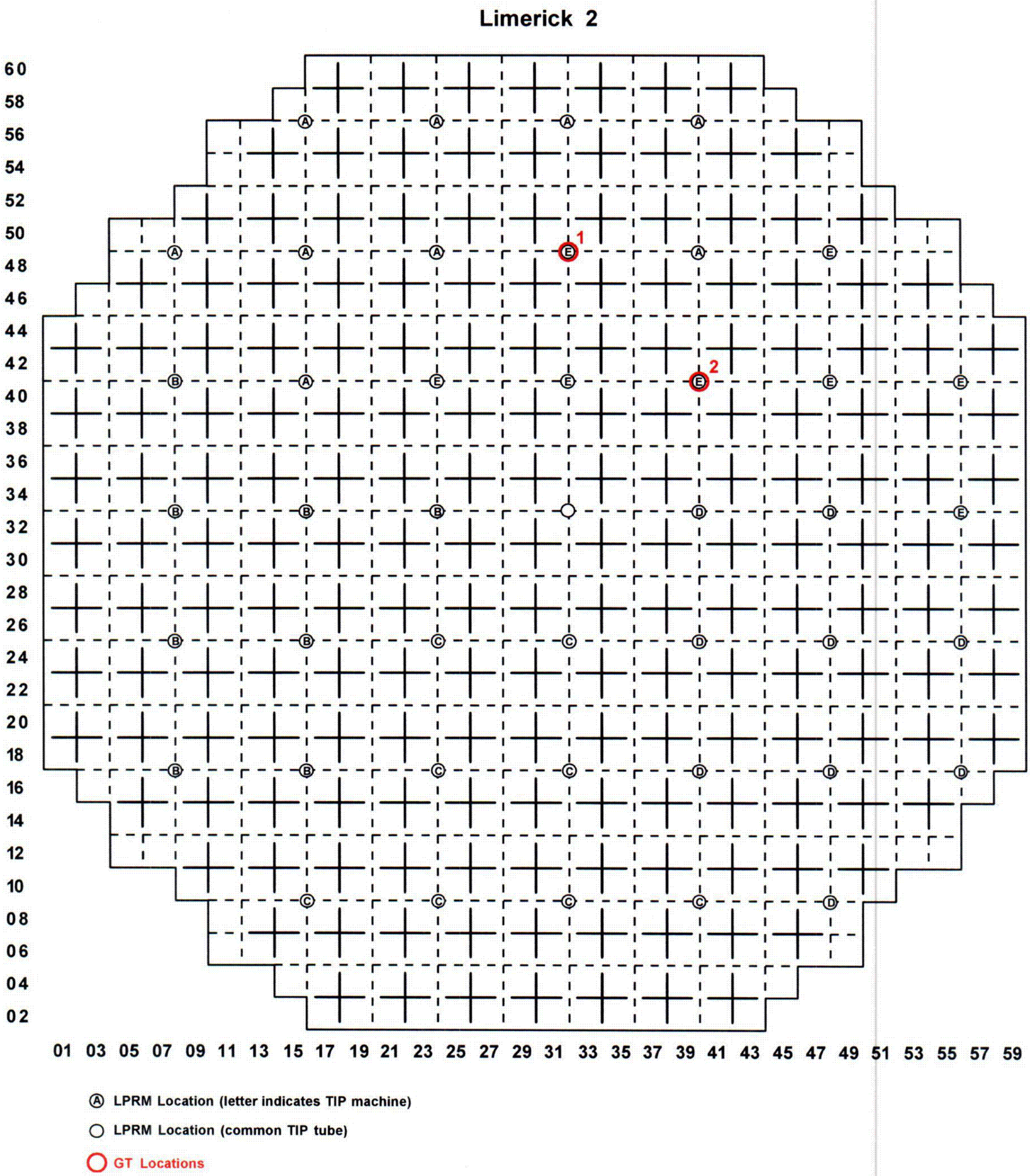


Figure 7-1, Limerick 2 Core Map

7.1.2 Hardware Description

[[

]]

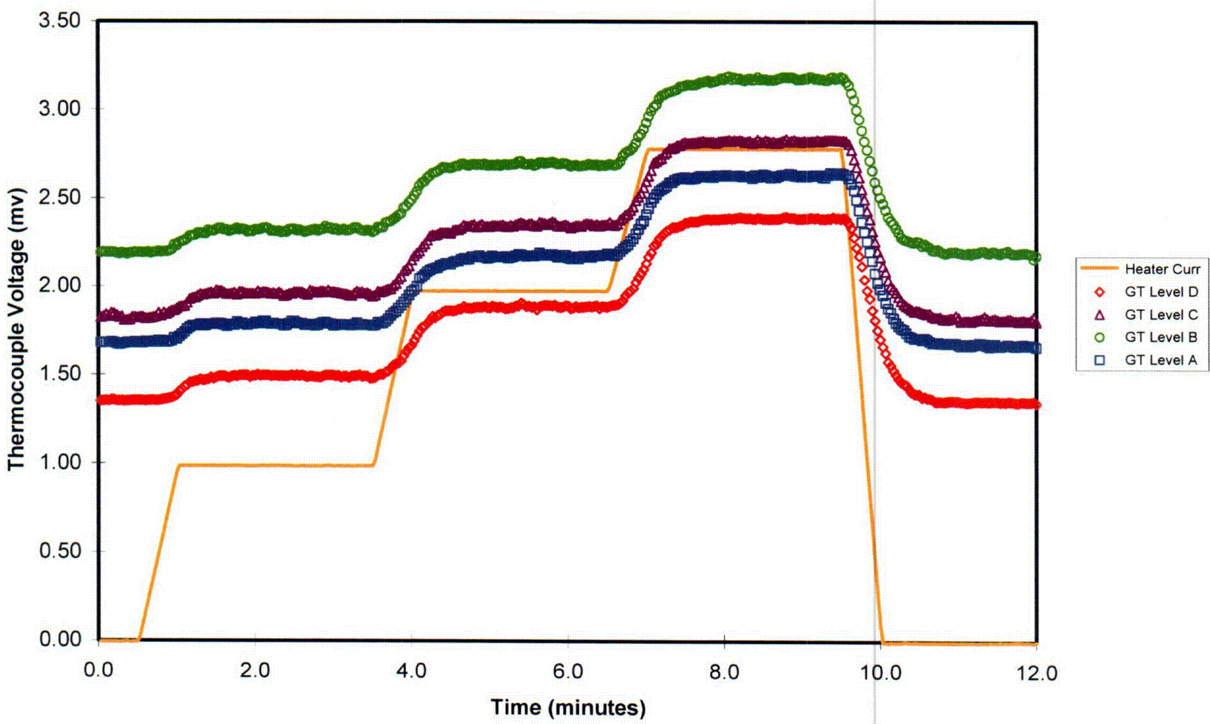


Figure 7-2, Heater Current During GT Calibration

C03

7.1.3 GT Calibration Results

[[

]]

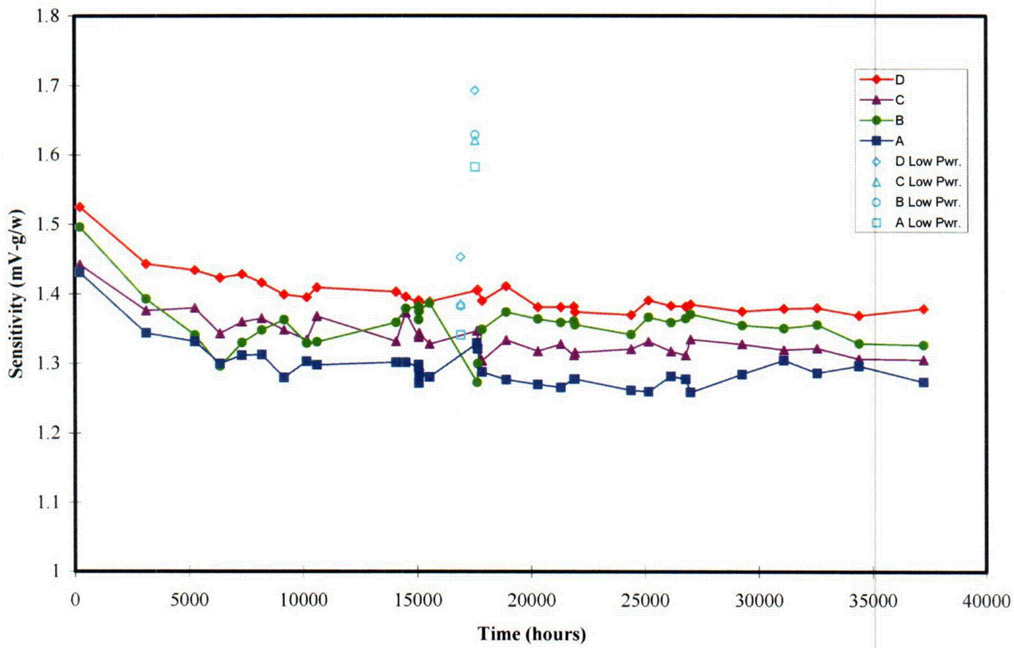


Figure 7-3, GT 1 Sensitivity

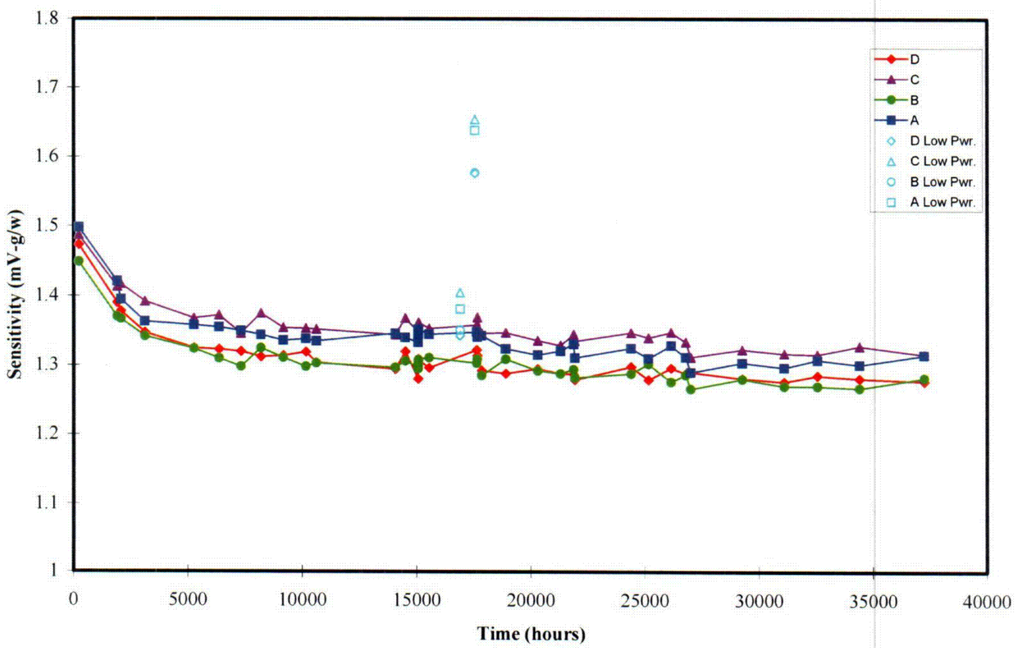


Figure 7-4, GT 2 Sensitivity

C04

[[

]]

Table 7-1, Coefficients for Sensitivity Model

	GT 1				GT 2			
	A	B	C	D	A	B	C	D
a	1.283E+00	1.351E+00	1.317E+00	1.382E+00	1.325E+00	1.290E+00	1.339E+00	1.293E+00
b	1.507E-01	1.686E-01	1.127E-01	1.405E-01	1.721E-01	1.561E-01	1.367E-01	1.789E-01
γ	-2.430E-04	-6.887E-04	-1.225E-04	-1.852E-04	-3.334E-04	-3.001E-04	-2.408E-04	-3.056E-04

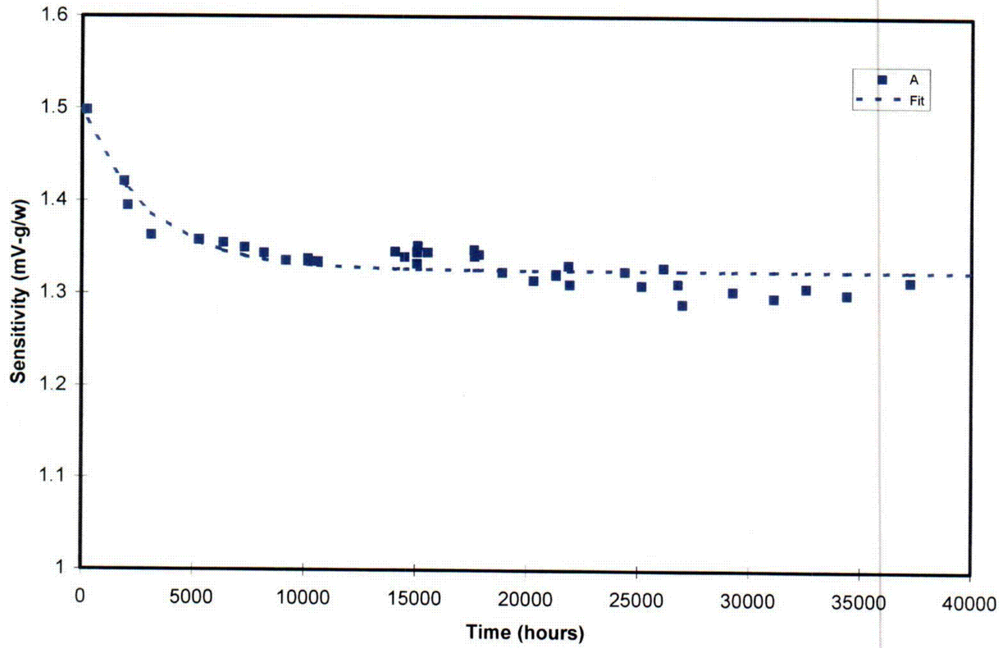


Figure 7-5, GT 2 Level A Sensitivity

7.1.4 <u>Comparison with Gamma TIPs</u>

[[

]]

C05

Table 7-2, Statistical Differences between GT and TIP Readings

	GT 1				GT 2			
	A	B	C	D	A	B	C	D
Ave. Err.	3.8%	-1.0%	-2.8%	-3.7%	1.3%	-2.4	-1.6	9.5%
Std. Dev.	2.9%	2.3%	1.5%	1.4%	2.1%	1.1%	0.9%	2.9%
Std. Err.	0.7%	0.5%	0.3%	0.3%	0.5%	0.3%	0.2%	0.7%

[[

]]

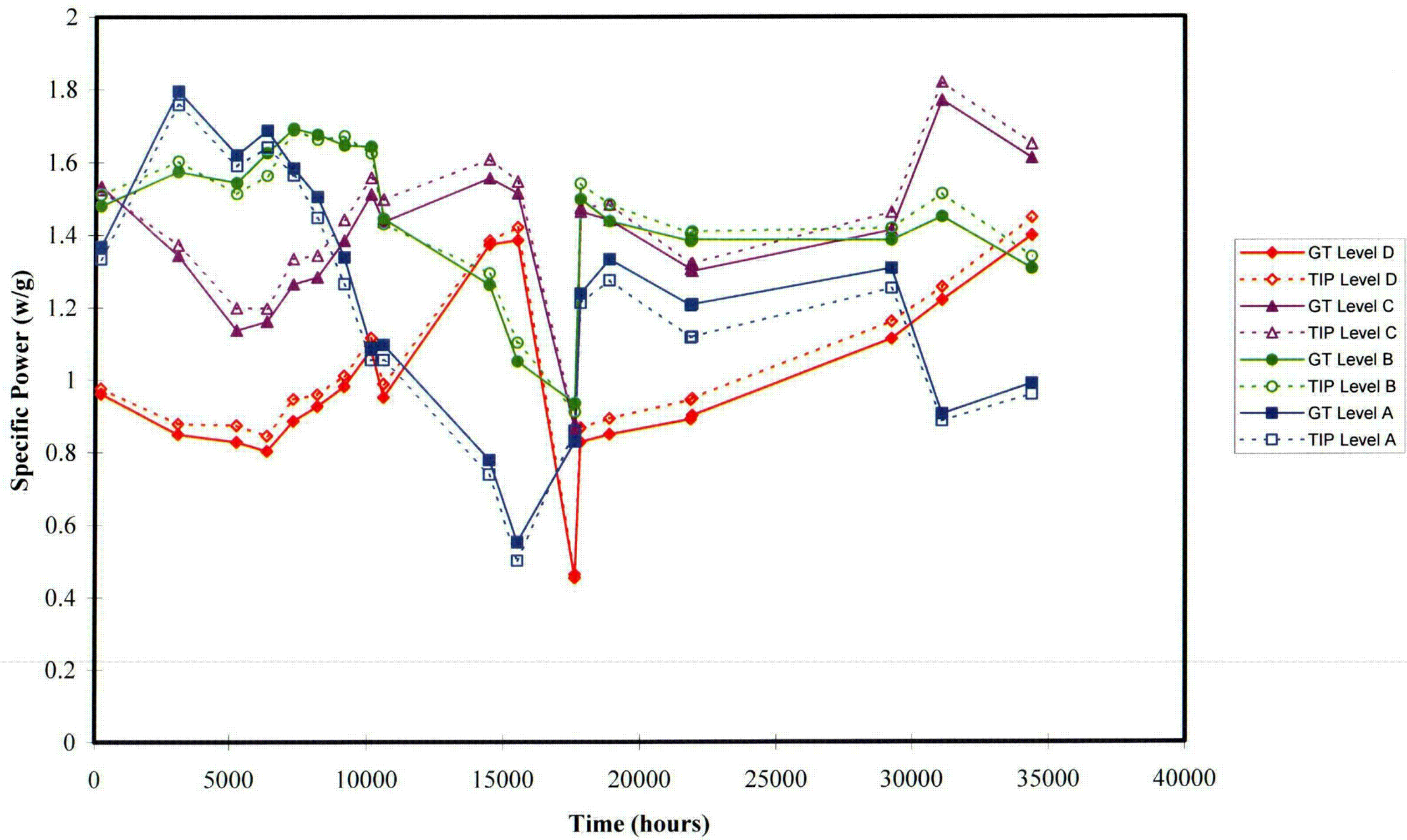


Figure 7-6, GT 1 vs. Gamma TIP

C06

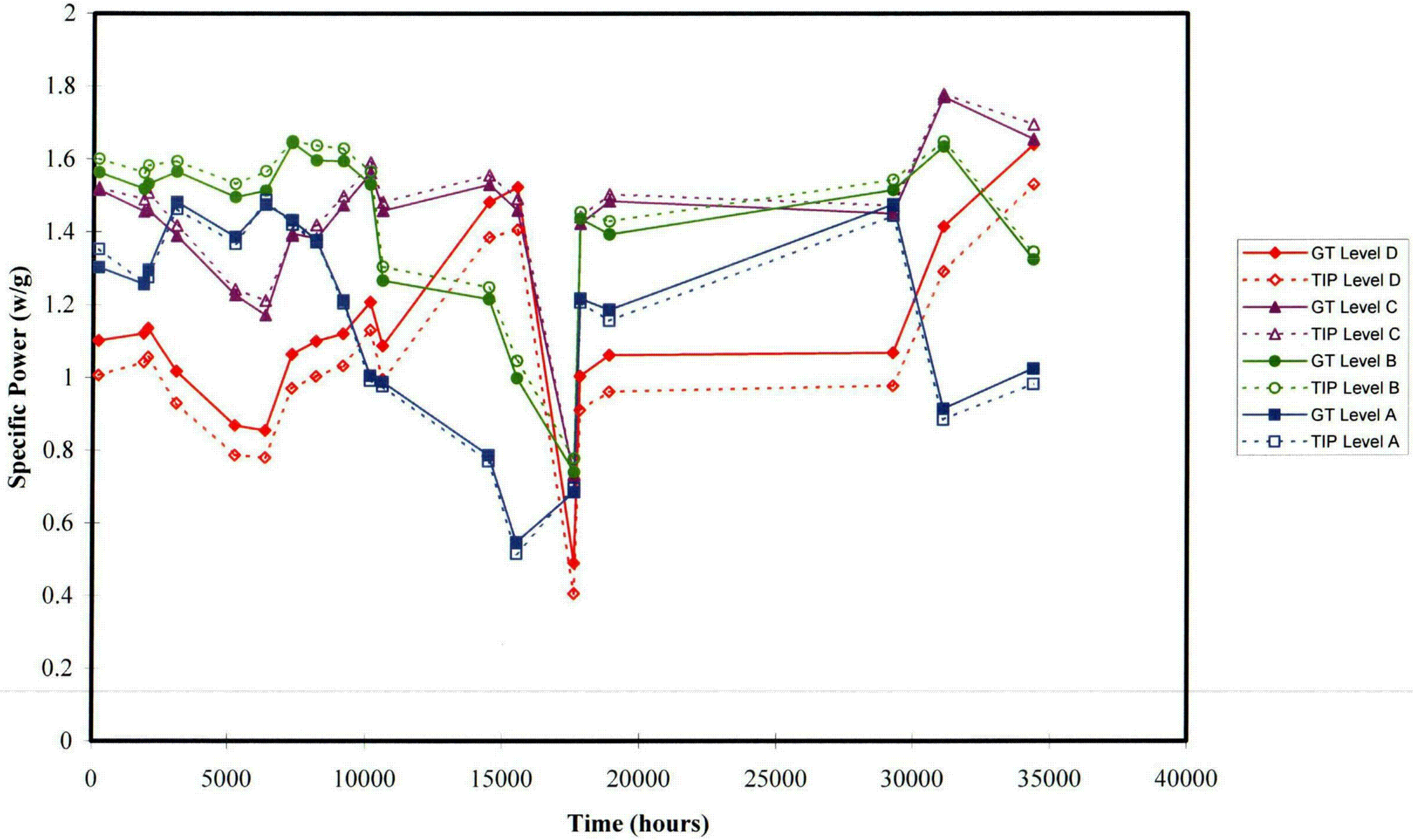


Figure 7-7, GT 2 vs. Gamma TIP

C07

7.1.5 Conclusions

[[

]]

7.2 Tokai 2 In-Plant Test

The Tokai 2 plant, operated by Japan Atomic Power Company (JAPC), is an 1100 MWe BWR5 with 764 fuel bundles arranged in a C lattice. It has a neutron sensitive TIP system with a total of 43 calibration tubes.

7.2.1 Test Plan

[[

]]

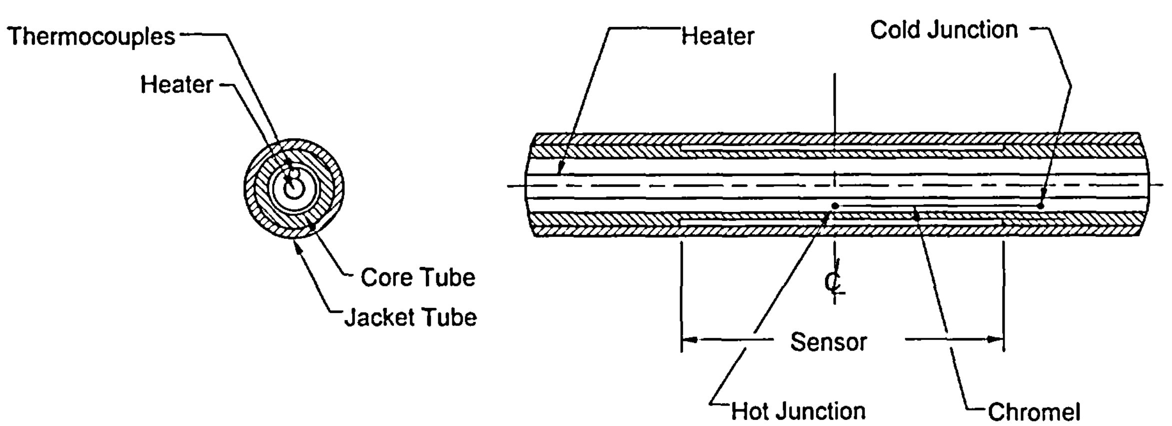


Figure 7-8, GT Sensor

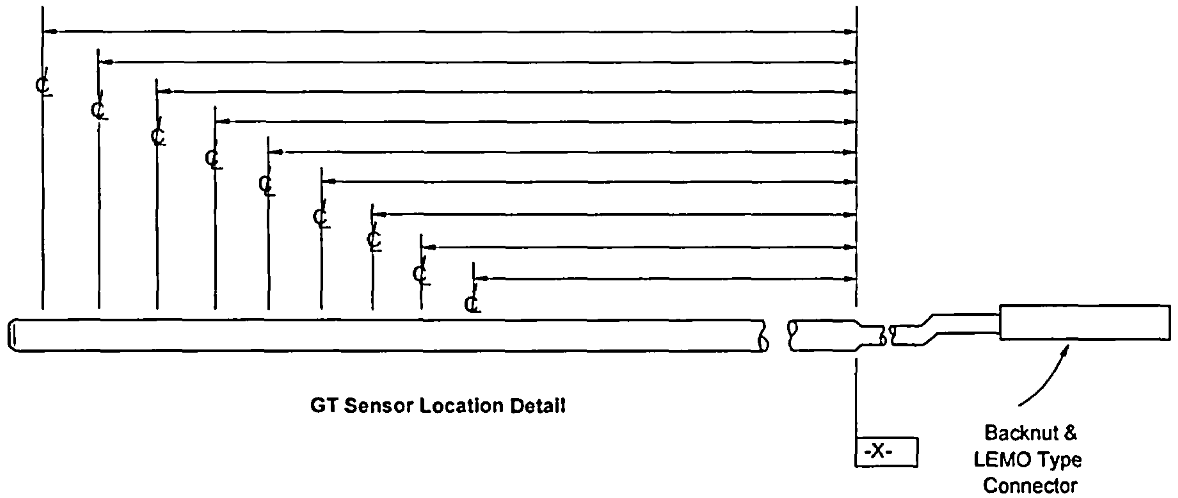


Figure 7-9, GT Rod

[[

]]

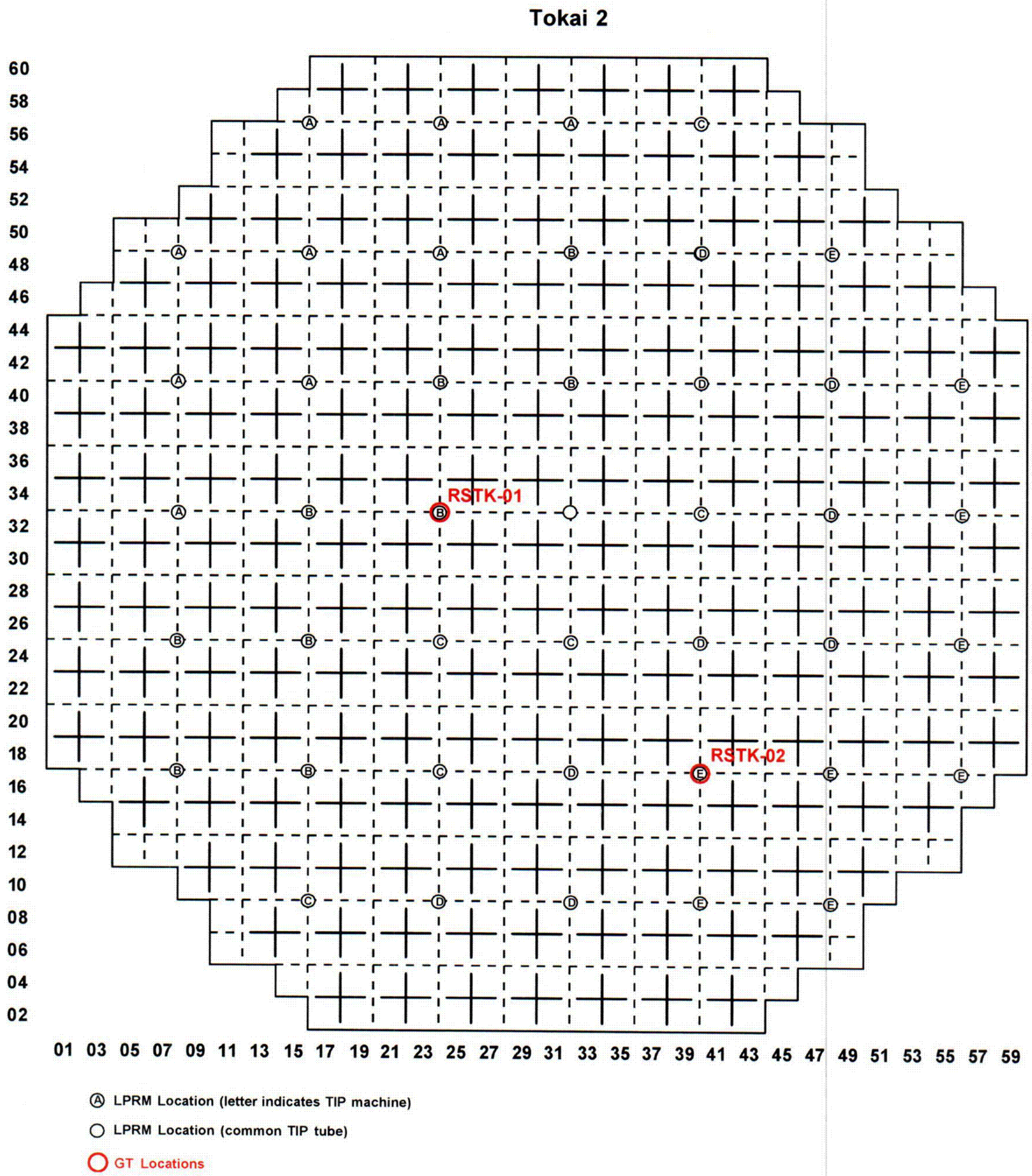


Figure 7-10, Tokai 2 Core Map

[[

]]

7.2.2 Hardware Description

[[

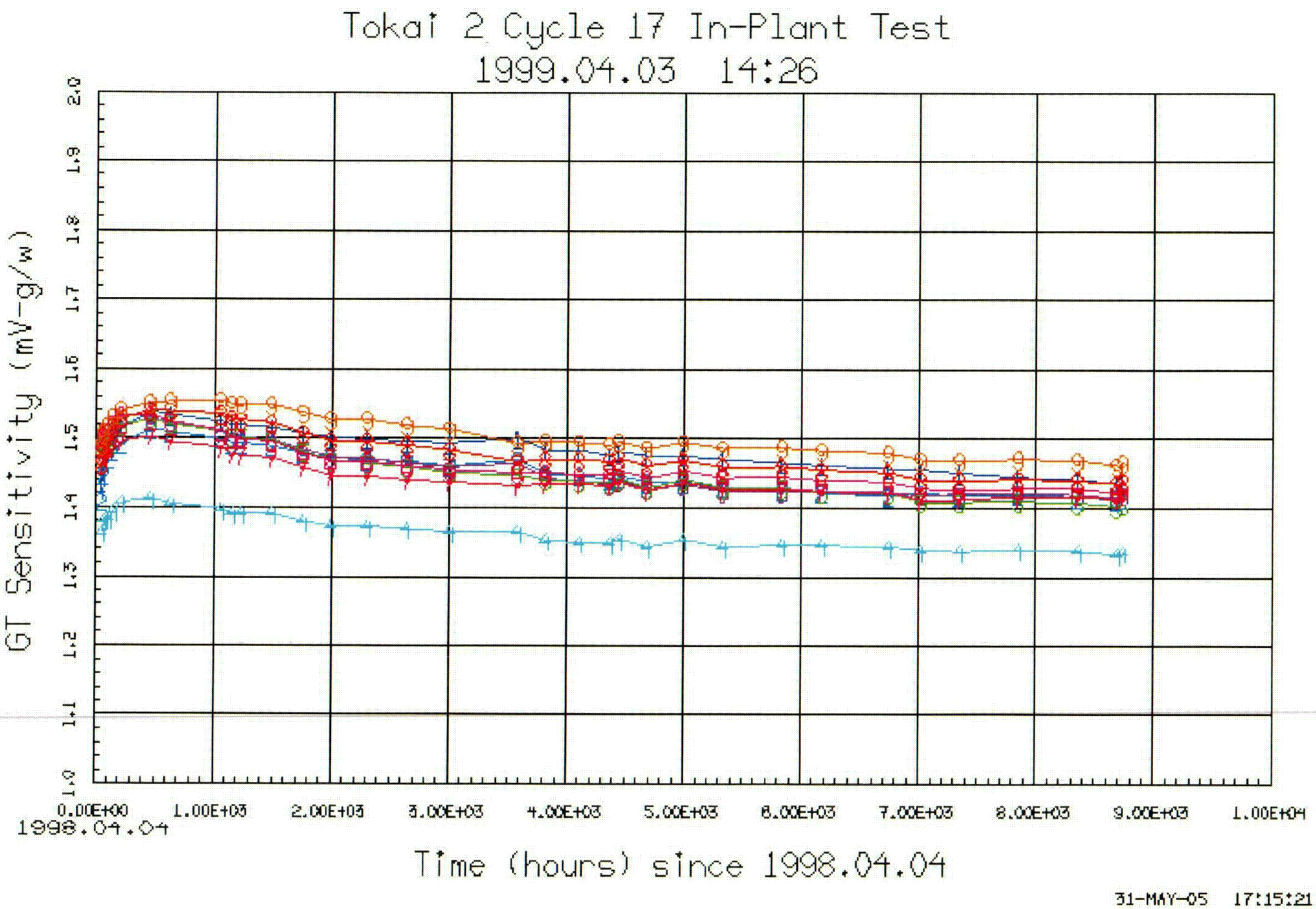
]]

7.2.3 GT Calibration Results

[[

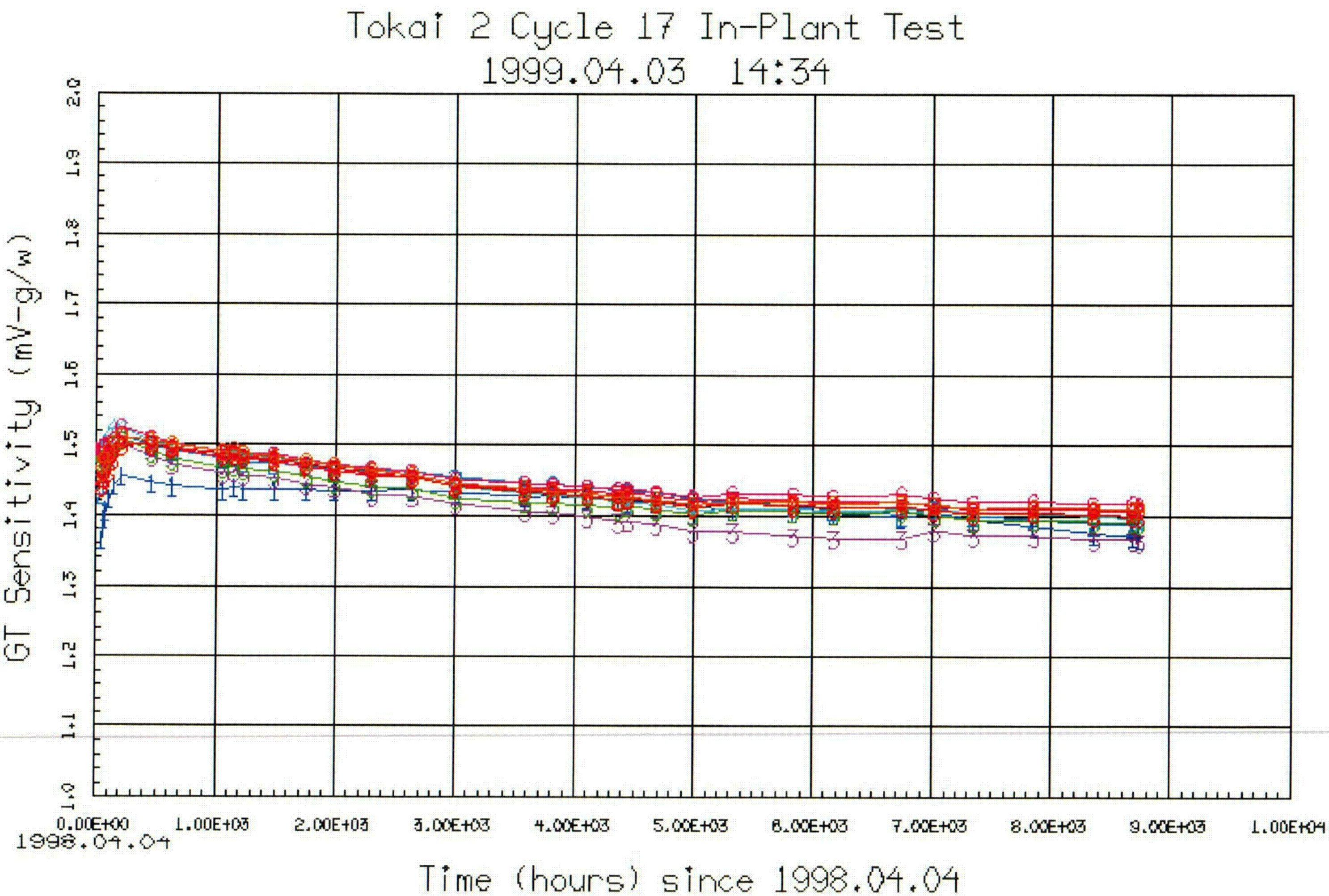
]]

Figure 7-11, Fixed Alpha GT Sensitivity for RSTK-01



C09

Figure 7-12, Fixed Alpha GT Sensitivity for RSTK-02



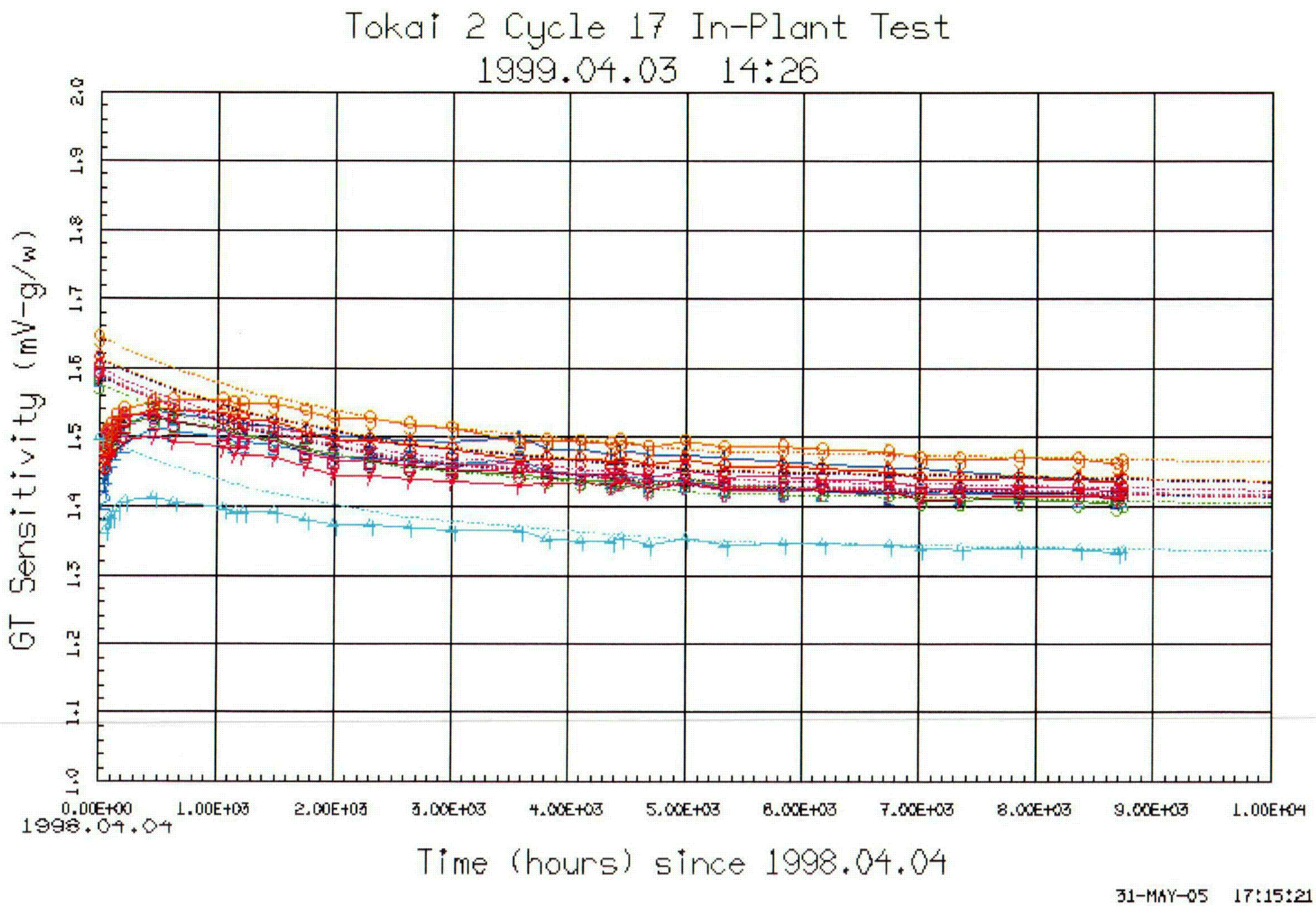
C10

7.2.4 GT Sensitivity Projection

[[

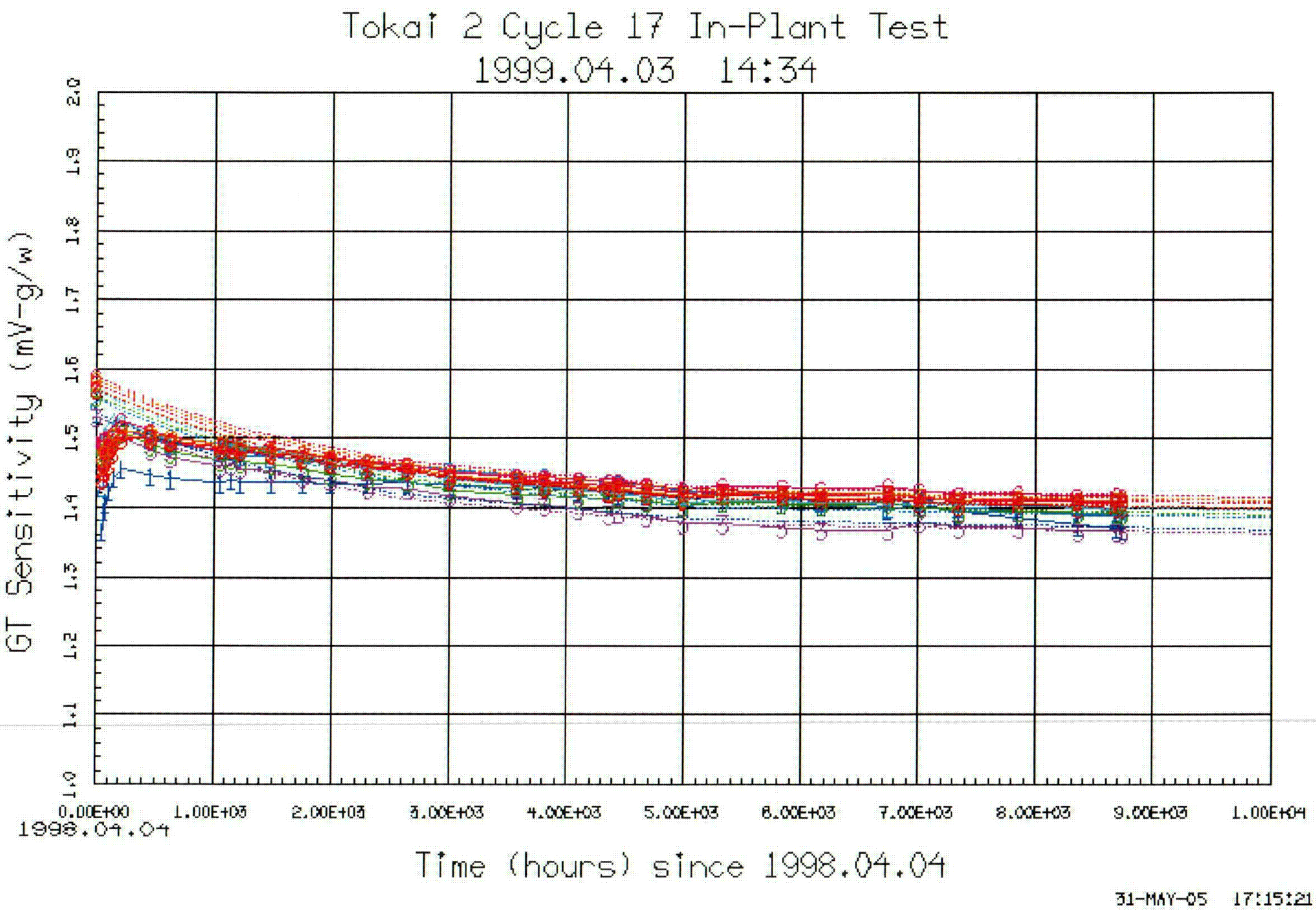
]]

Figure 7-13, Fixed Alpha GT Sensitivity Projection for RSTK-01



C11

Figure 7-14, Fixed Alpha GT Sensitivity Projection for RSTK-02



C12

7.2.5 Steady State Response

7.2.5.1 Comparison with Neutron TIPs

[[

]]

Table 7-3, Difference (%)* between GT** and TIP Readings for RSTK-01

Cal. #	Date	Power %	Sensor ⇒ 1	2	3	4	5	6	7	8	9
1	19980406	29.2	5.6	4.5	-0.4	1.0	-0.4	-1.7	-2.3	2.9	-0.3
2	19980406	55.8	-3.5	-2.8	2.0	2.5	-2.0	-2.3	-4.1	-1.3	-5.1
3	19980407	83.3	-5.5	-2.7	2.8	4.2	-0.2	-2.0	-3.6	-1.9	-5.7
18	19990401	92.3	-1.6	-0.2	2.2	2.6	-1.1	-2.3	-5.4	-2.4	-7.5
	Mean	**<95.0**	**-1.3**	**-0.3**	**1.7**	**2.6**	**-0.9**	**-2.1**	**-3.8**	**-0.7**	**-4.6**
	StDev	**<95.0**	**4.8**	**3.4**	**1.4**	**1.3**	**0.8**	**0.3**	**1.3**	**2.4**	**3.1**
	StErr	**<95.0**	**2.4**	**1.7**	**0.7**	**0.7**	**0.4**	**0.2**	**0.6**	**1.2**	**1.5**
4	19980413	99.7	-3.8	-3.3	1.7	3.6	-2.0	-2.0	-4.5	-3.3	-7.1
5	19980423	99.6	-1.9	-1.5	3.9	4.3	0.1	-2.3	-3.0	-2.7	-5.9
6	19980430	99.6	-1.5	-0.3	4.2	4.3	-1.3	-1.8	-4.0	-2.5	-5.6
7	19980518	99.4	-2.4	-1.2	3.7	3.9	-2.0	-2.3	-3.9	-3.3	-7.3
8	19980525	99.5	-2.3	-1.7	4.0	4.0	-2.5	-2.4	-3.9	-3.0	-7.0
9	19980605	99.5	-2.2	-2.1	1.2	2.4	-3.4	-3.2	-5.2	-4.8	-8.9
10	19980616	99.5	-3.3	-2.3	2.4	1.4	0.4	-2.9	-4.7	-4.9	-8.9
11	19980723	99.8	-1.5	-1.4	3.3	4.4	-1.3	-1.3	-4.1	-2.4	-6.9
12	19980831	99.8	-2.9	0.6	3.2	3.2	-1.7	-1.9	-5.0	-2.4	-6.9
13	19981006	99.7	-1.9	-0.1	3.9	4.5	-0.2	-1.2	-2.2	-2.9	-7.2
14	19981112	99.5	-2.6	-0.3	1.5	3.0	-1.0	-1.1	-4.9	-4.0	-8.1
15	19981217	99.5	-1.7	1.2	3.2	3.5	0.1	-1.1	-4.1	-2.0	-6.7
16	19990121	99.4	-2.6	-0.6	3.7	4.7	-1.5	-1.2	-4.1	-3.0	-7.9
17	19990225	98.7	-1.4	0.5	3.4	3.2	-0.7	-1.7	-5.2	-2.8	-8.4
	Mean	**≥95.0**	**-2.3**	**-0.9**	**3.1**	**3.6**	**-1.2**	**-1.9**	**-4.2**	**-3.1**	**-7.3**
	StDev	**≥95.0**	**0.7**	**1.3**	**1.0**	**0.9**	**1.1**	**0.7**	**0.9**	**0.9**	**1.0**
	StErr	**≥95.0**	**0.2**	**0.3**	**0.3**	**0.2**	**0.3**	**0.2**	**0.2**	**0.2**	**0.3**
	Mean	**All**	**-2.1**	**-0.8**	**2.8**	**3.4**	**-1.2**	**-1.9**	**-4.1**	**-2.6**	**-6.7**
	StDev	**All**	**2.2**	**1.8**	**1.2**	**1.1**	**1.0**	**0.6**	**0.9**	**1.6**	**2.0**
	StErr	**All**	**0.5**	**0.4**	**0.3**	**0.3**	**0.2**	**0.1**	**0.2**	**0.4**	**0.5**

* $\varepsilon_i^{(k)} = 100 \cdot (GT_i - TIP_i) / TIP_i$

** GT readings have been converted to equivalent fission detector readings.

Table 7-4, Difference (%)* between GT and TIP Readings for RSTK-02**

Cal. #	Date	Power %	Sensor ⇒ 1	2	3	4	5	6	7	8	9
1	19980406	29.2	5.8	-0.4	-3.3	0.0	0.6	-0.9	-1.2	2.8	2.7
2	19980406	55.8	1.3	1.6	4.4	7.2	4.3	1.4	-1.1	-0.1	-3.7
3	19980407	83.3	0.7	2.2	5.8	6.6	2.2	0.0	-1.8	1.0	-3.1
18	19990401	92.3	-1.4	2.0	5.8	6.5	1.3	0.5	-1.8	0.7	-2.9
	Mean	**<95.0**	**1.6**	**1.4**	**3.2**	**5.1**	**2.1**	**0.3**	**-1.5**	**1.1**	**-1.8**
	StDev	**<95.0**	**3.0**	**1.2**	**4.4**	**3.4**	**1.6**	**1.0**	**0.4**	**1.2**	**3.0**
	StErr	**<95.0**	**1.5**	**0.6**	**2.2**	**1.7**	**0.8**	**0.5**	**0.2**	**0.6**	**1.5**
4	19980413	99.7	0.4	3.3	7.2	7.5	2.4	0.5	-1.8	-0.1	-3.4
5	19980423	99.6	-2.1	1.6	5.8	6.1	2.3	-1.1	-3.1	-1.7	-4.5
6	19980430	99.6	0.8	2.2	4.1	5.8	1.1	-1.1	-3.1	-1.2	-4.1
7	19980518	99.4	0.8	3.8	5.1	5.8	1.2	-0.4	-1.7	0.1	-3.1
8	19980525	99.5	2.2	3.3	4.3	6.8	3.3	0.0	-2.1	-0.8	-3.8
9	19980605	99.5	4.3	4.6	5.3	8.8	2.6	2.1	-0.7	2.4	-1.3
10	19980616	99.5	3.5	4.7	5.1	7.5	3.5	1.3	-1.1	0.7	-2.4
11	19980723	99.8	0.9	2.9	4.3	6.2	2.0	0.5	-2.4	-0.3	-3.0
12	19980831	99.8	1.7	3.4	4.3	6.9	2.2	1.4	-1.5	-0.8	-2.6
13	19981006	99.7	-0.2	1.2	4.4	4.8	1.1	0.5	-2.9	0.0	-3.2
14	19981112	99.5	0.4	4.0	5.5	9.0	2.4	0.3	-1.1	0.4	-4.1
15	19981217	99.5	-1.6	2.6	4.1	5.4	1.4	0.2	-2.0	-0.2	-4.1
16	19990121	99.4	-2.7	1.9	5.2	6.6	1.5	-0.4	-2.7	-0.5	-4.7
17	19990225	98.7	-1.5	1.8	5.3	6.3	2.0	-0.5	-2.9	0.0	-4.4
	Mean	**≥95.0**	**0.5**	**3.0**	**5.0**	**6.7**	**2.1**	**0.2**	**-2.1**	**-0.1**	**-3.5**
	StDev	**≥95.0**	**2.0**	**1.1**	**0.9**	**1.2**	**0.8**	**0.9**	**0.8**	**1.0**	**0.9**
	StErr	**≥95.0**	**0.5**	**0.3**	**0.2**	**0.3**	**0.2**	**0.2**	**0.2**	**0.3**	**0.3**
	Mean	**All**	**0.7**	**2.6**	**4.6**	**6.3**	**2.1**	**0.2**	**-1.9**	**0.1**	**-3.1**
	StDev	**All**	**2.2**	**1.3**	**2.1**	**1.9**	**1.0**	**0.9**	**0.8**	**1.1**	**1.7**
	StErr	**All**	**0.5**	**0.3**	**0.5**	**0.4**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**

* $\varepsilon_i^{(k)} = 100 \cdot (GT_i - TIP_i) / TIP_i$

** GT readings have been converted to equivalent fission detector readings.

Table 7-5, Difference (rd)* between GT** and TIP Readings for RSTK-01

Cal. #	Date	Power %	Sensor ⇒ 1	2	3	4	5	6	7	8	9
1	19980406	29.2	0.9	1.3	-0.3	1.8	-0.8	-2.5	-2.5	2.2	-0.1
2	19980406	55.8	-1.4	-1.3	4.1	5.0	-0.6	-0.9	-2.7	0.2	-2.3
3	19980407	83.3	-4.0	-1.8	5.0	5.9	1.2	-0.7	-2.2	-0.5	-2.9
18	19990401	92.3	0.0	1.3	4.1	4.7	0.6	-0.8	-4.4	-0.7	-4.7
	Mean	**<95.0**	**-1.1**	**-0.1**	**3.2**	**4.4**	**0.1**	**-1.3**	**-3.0**	**0.3**	**-2.5**
	StDev	**<95.0**	**2.1**	**1.7**	**2.4**	**1.8**	**0.9**	**0.9**	**1.0**	**1.4**	**1.9**
	StErr	**<95.0**	**1.1**	**0.8**	**1.2**	**0.9**	**0.5**	**0.4**	**0.5**	**0.7**	**1.0**
4	19980413	99.7	-1.4	-1.5	4.4	6.3	0.0	0.0	-2.7	-1.2	-3.9
5	19980423	99.6	-0.9	-0.8	5.3	5.6	0.9	-1.8	-2.5	-1.8	-4.0
6	19980430	99.6	-0.5	0.4	5.5	5.6	-0.7	-1.2	-3.7	-1.7	-3.7
7	19980518	99.4	-0.7	0.1	5.7	5.9	-0.7	-1.1	-2.8	-1.8	-4.7
8	19980525	99.5	-0.6	-0.3	5.9	6.3	-1.3	-1.1	-2.9	-1.5	-4.5
9	19980605	99.5	0.3	0.6	4.4	6.0	-0.8	-0.6	-2.9	-2.0	-5.1
10	19980616	99.5	-0.7	-0.1	5.1	4.3	3.2	-0.8	-2.9	-2.6	-5.6
11	19980723	99.8	-0.2	-0.3	4.5	6.3	-0.2	-0.2	-3.6	-1.4	-5.0
12	19980831	99.8	-0.7	1.6	4.7	5.4	-0.2	-0.5	-4.4	-1.0	-4.9
13	19981006	99.7	-0.7	0.4	4.5	5.8	0.5	-0.7	-1.8	-2.4	-5.7
14	19981112	99.5	-0.4	1.1	3.3	5.6	1.1	1.0	-3.8	-2.3	-5.6
15	19981217	99.5	-0.5	1.4	3.9	4.9	1.1	-0.4	-4.1	-1.2	-5.2
16	19990121	99.4	-1.1	0.4	5.4	6.4	-0.5	-0.2	-3.4	-1.7	-5.2
17	19990225	98.7	-0.1	1.7	5.1	5.0	0.5	-0.6	-4.5	-1.5	-5.6
	Mean	**≥95.0**	**-0.6**	**0.4**	**4.8**	**5.7**	**0.2**	**-0.6**	**-3.3**	**-1.7**	**-4.9**
	StDev	**≥95.0**	**0.4**	**0.9**	**0.7**	**0.6**	**1.1**	**0.7**	**0.8**	**0.5**	**0.7**
	StErr	**≥95.0**	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**	**0.2**	**0.2**	**0.1**	**0.2**
	Mean	**All**	**-0.7**	**0.2**	**4.5**	**5.4**	**0.2**	**-0.7**	**-3.2**	**-1.3**	**-4.4**
	StDev	**All**	**1.0**	**1.1**	**1.4**	**1.1**	**1.1**	**0.7**	**0.8**	**1.1**	**1.4**
	StErr	**All**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.3**	**0.3**

* $\delta_i = 100 \cdot \left(GT_i / \frac{1}{9}\sum_{j=1}^{9} GT_j - TIP_i / \frac{1}{9}\sum_{j=1}^{9} TIP_j \right)$

** GT readings have been converted to equivalent fission detector readings.

Table 7-6, Difference (rd)* between GT and TIP Readings for RSTK-02**

Cal. #	Date	Power %	Sensor ⇒ 1	2	3	4	5	6	7	8	9
1	19980406	29.2	1.4	-0.2	-3.0	0.0	1.0	-1.5	-1.4	2.1	1.6
2	19980406	55.8	-0.5	-0.3	2.8	5.7	2.6	-0.5	-3.2	-2.0	-4.6
3	19980407	83.3	-0.5	0.5	3.9	5.1	0.9	-2.0	-3.9	-0.5	-3.6
18	19990401	92.3	-2.2	0.5	5.0	5.4	-0.3	-1.1	-3.5	-0.7	-3.2
	Mean	**<95.0**	**-0.4**	**0.1**	**2.2**	**4.0**	**1.1**	**-1.3**	**-3.0**	**-0.3**	**-2.4**
	StDev	**<95.0**	**1.5**	**0.5**	**3.5**	**2.7**	**1.2**	**0.6**	**1.1**	**1.7**	**2.8**
	StErr	**<95.0**	**0.7**	**0.2**	**1.8**	**1.4**	**0.6**	**0.3**	**0.6**	**0.9**	**1.4**
4	19980413	99.7	-1.3	1.2	5.7	5.8	0.3	-1.8	-4.0	-1.9	-3.9
5	19980423	99.6	-2.1	0.9	5.7	5.9	1.7	-2.0	-4.1	-2.2	-3.8
6	19980430	99.6	0.1	1.5	3.9	5.6	0.4	-2.0	-4.1	-1.7	-3.6
7	19980518	99.4	-0.5	2.2	4.0	4.8	-0.3	-2.2	-3.4	-1.2	-3.4
8	19980525	99.5	0.3	1.2	2.9	6.4	2.2	-2.0	-4.4	-2.3	-4.3
9	19980605	99.5	0.5	1.0	2.3	6.8	-0.7	-1.2	-4.5	-0.7	-3.5
10	19980616	99.5	0.4	1.4	2.7	6.1	1.2	-1.6	-4.3	-1.8	-4.0
11	19980723	99.8	-0.1	1.0	2.7	6.2	1.0	-1.0	-4.5	-1.6	-3.6
12	19980831	99.8	0.0	0.9	2.3	6.5	0.8	-0.3	-4.0	-2.6	-3.7
13	19981006	99.7	-0.3	0.3	3.2	4.9	0.6	-0.2	-4.5	-0.7	-3.3
14	19981112	99.5	-0.6	1.2	3.1	8.2	0.6	-2.1	-3.7	-1.6	-5.2
15	19981217	99.5	-1.0	1.1	3.0	5.5	0.8	-0.8	-3.4	-1.1	-4.2
16	19990121	99.4	-2.9	1.1	5.1	6.4	0.6	-1.4	-3.7	-1.2	-3.9
17	19990225	98.7	-2.1	0.8	5.1	5.8	1.0	-1.8	-4.1	-1.0	-3.8
	Mean	**≥95.0**	**-0.7**	**1.1**	**3.7**	**6.1**	**0.7**	**-1.5**	**-4.1**	**-1.5**	**-3.9**
	StDev	**≥95.0**	**1.1**	**0.4**	**1.2**	**0.8**	**0.7**	**0.7**	**0.4**	**0.6**	**0.5**
	StErr	**≥95.0**	**0.3**	**0.1**	**0.3**	**0.2**	**0.2**	**0.2**	**0.1**	**0.2**	**0.1**
	Mean	**All**	**-0.6**	**0.9**	**3.4**	**5.6**	**0.8**	**-1.4**	**-3.8**	**-1.2**	**-3.6**
	StDev	**All**	**1.1**	**0.6**	**1.9**	**1.6**	**0.8**	**0.6**	**0.7**	**1.0**	**1.4**
	StErr	**All**	**0.3**	**0.1**	**0.5**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**

* $\delta_i = 100 \cdot \left(GT_i / \frac{1}{9}\sum_{j=1}^{9} GT_j - TIP_i / \frac{1}{9}\sum_{j=1}^{9} TIP_j \right)$

** GT readings have been converted to equivalent fission detector readings.

Table 7-7, Difference (rd)[*] between GT and TIP Four-Bundle Powers for RSTK-01

Cal. #	Date	Power %	Sensor ⇒ 1	2	3	4	5	6	7	8	9
1	19980406	29.2	0.6	0.9	-0.7	0.8	-1.5	-2.4	-2.3	2.8	1.7
2	19980406	55.8	-1.7	-1.1	3.3	4.0	-1.2	-1.1	-2.8	1.0	-0.5
3	19980407	83.3	-4.0	-1.7	3.6	4.8	0.9	-0.7	-2.2	0.4	-1.1
18	19990401	92.3	-0.1	1.5	3.4	3.7	0.1	-1.0	-4.5	-0.1	-3.1
	Mean	**<95.0**	**-1.3**	**-0.1**	**2.4**	**3.3**	**-0.4**	**-1.3**	**-2.9**	**1.0**	**-0.7**
	StDev	**<95.0**	**2.1**	**1.5**	**2.1**	**1.8**	**1.1**	**0.7**	**1.1**	**1.3**	**2.0**
	StErr	**<95.0**	**1.0**	**0.8**	**1.0**	**0.9**	**0.5**	**0.4**	**0.5**	**0.6**	**1.0**
4	19980413	99.7	-1.3	-0.9	3.3	5.4	-0.2	0.1	-2.9	-1.0	-2.5
5	19980423	99.6	-1.2	-0.8	4.1	4.7	0.6	-2.0	-2.3	-1.0	-2.0
6	19980430	99.6	-0.7	0.4	4.2	4.2	-1.5	-1.5	-3.5	-0.5	-1.2
7	19980518	99.4	-0.5	0.6	4.6	4.6	-1.8	-1.8	-2.9	-0.6	-2.2
8	19980525	99.5	-0.7	-0.1	4.7	5.1	-1.8	-1.2	-2.9	-0.6	-2.5
9	19980605	99.5	0.1	0.7	3.4	4.7	-1.3	-0.7	-2.8	-1.1	-3.0
10	19980616	99.5	-1.0	-0.2	3.8	3.1	2.7	-0.7	-2.7	-1.5	-3.3
11	19980723	99.8	-0.8	-0.7	3.2	4.9	-1.1	-0.7	-3.2	0.3	-2.0
12	19980831	99.8	-0.6	1.8	3.9	4.1	-0.9	-0.8	-4.7	-0.1	-2.8
13	19981006	99.7	-0.6	0.8	3.9	5.0	0.3	-0.9	-2.2	-2.1	-4.2
14	19981112	99.5	0.0	1.8	3.1	4.6	0.4	0.5	-4.3	-2.0	-4.2
15	19981217	99.5	-0.9	1.1	2.7	3.3	0.2	-0.6	-3.6	0.2	-2.6
16	19990121	99.4	-1.1	0.8	4.4	5.3	-0.9	-0.2	-3.4	-1.1	-3.8
17	19990225	98.7	0.0	2.0	4.4	4.3	0.4	-0.6	-4.8	-1.3	-4.5
	Mean	**≥95.0**	**-0.7**	**0.5**	**3.8**	**4.5**	**-0.3**	**-0.8**	**-3.3**	**-0.9**	**-2.9**
	StDev	**≥95.0**	**0.4**	**1.0**	**0.6**	**0.7**	**1.2**	**0.7**	**0.8**	**0.7**	**1.0**
	StErr	**≥95.0**	**0.1**	**0.3**	**0.2**	**0.2**	**0.3**	**0.2**	**0.2**	**0.2**	**0.3**
	Mean	**All**	**-0.8**	**0.4**	**3.5**	**4.3**	**-0.4**	**-0.9**	**-3.2**	**-0.4**	**-2.4**
	StDev	**All**	**1.0**	**1.1**	**1.2**	**1.1**	**1.2**	**0.7**	**0.8**	**1.2**	**1.5**
	StErr	**All**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.2**	**0.2**	**0.3**	**0.4**

[*] $\delta_i = 100 \cdot \left(P4B_i^{GT} / \frac{1}{9}\sum_{j=1}^{9} P4B_j^{GT} - P4B_i^{TIP} / \frac{1}{9}\sum_{j=1}^{9} P4B_j^{TIP} \right)$

Table 7-8, Difference (rd)* between GT and TIP Four-Bundle Powers for RSTK-02

Cal. #	Date	Power %	Sensor ⇒ 1	2	3	4	5	6	7	8	9
1	19980406	29.2	1.0	-0.4	-3.3	-1.1	0.5	-1.3	-1.4	2.5	3.4
2	19980406	55.8	-1.2	-0.7	2.0	5.3	3.1	0.2	-2.8	-2.4	-3.5
3	19980407	83.3	-0.8	0.5	3.5	5.1	0.1	-2.4	-4.4	0.2	-1.8
18	19990401	92.3	-2.4	0.6	3.8	4.4	-0.5	-1.1	-3.4	0.1	-1.4
	Mean	**<95.0**	**-0.9**	**0.0**	**1.5**	**3.4**	**0.8**	**-1.2**	**-3.0**	**0.1**	**-0.8**
	StDev	**<95.0**	**1.4**	**0.6**	**3.3**	**3.0**	**1.6**	**1.1**	**1.3**	**2.0**	**3.0**
	StErr	**<95.0**	**0.7**	**0.3**	**1.6**	**1.5**	**0.8**	**0.5**	**0.6**	**1.0**	**1.5**
4	19980413	99.7	-2.0	0.8	4.1	4.5	-0.1	-1.6	-3.5	-0.5	-1.6
5	19980423	99.6	-2.3	0.9	4.4	4.9	1.4	-2.1	-4.1	-1.3	-1.9
6	19980430	99.6	-0.2	1.5	2.8	4.4	-0.3	-2.4	-3.9	-0.6	-1.3
7	19980518	99.4	-0.7	2.2	3.0	3.8	-0.8	-2.4	-3.3	-0.4	-1.4
8	19980525	99.5	0.2	1.3	2.7	5.2	1.6	-2.2	-4.6	-1.7	-2.4
9	19980605	99.5	0.1	0.8	1.9	5.7	-1.2	-1.5	-4.7	0.2	-1.5
10	19980616	99.5	0.1	1.3	2.4	4.9	0.7	-1.8	-4.4	-1.1	-2.0
11	19980723	99.8	-0.1	1.2	2.6	4.6	-1.0	-2.7	-4.7	0.3	-0.2
12	19980831	99.8	0.1	1.3	2.6	5.9	0.7	-0.3	-4.7	-2.8	-2.7
13	19981006	99.7	-0.7	0.2	2.8	4.3	0.1	-0.5	-4.8	-0.2	-1.3
14	19981112	99.5	-0.7	1.2	2.4	6.6	0.4	-1.4	-3.6	-1.2	-3.8
15	19981217	99.5	-1.1	1.2	3.4	5.7	-0.2	-2.5	-4.3	-0.3	-1.9
16	19990121	99.4	-2.7	1.5	3.8	5.1	-0.2	-1.6	-3.6	-0.3	-2.1
17	19990225	98.7	-1.6	1.5	4.0	4.3	0.5	-1.9	-4.3	-0.3	-2.2
	Mean	**≥95.0**	**-0.8**	**1.2**	**3.1**	**5.0**	**0.1**	**-1.8**	**-4.2**	**-0.7**	**-1.9**
	StDev	**≥95.0**	**1.0**	**0.5**	**0.8**	**0.8**	**0.8**	**0.7**	**0.5**	**0.8**	**0.8**
	StErr	**≥95.0**	**0.3**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.1**	**0.2**	**0.2**
	Mean	**All**	**-0.8**	**0.9**	**2.7**	**4.7**	**0.3**	**-1.6**	**-3.9**	**-0.5**	**-1.6**
	StDev	**All**	**1.0**	**0.7**	**1.7**	**1.6**	**1.0**	**0.8**	**0.9**	**1.2**	**1.5**
	StErr	**All**	**0.2**	**0.2**	**0.4**	**0.4**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**

* $\delta_i = 100 \cdot \left(P4B_i^{GT} / \frac{1}{9}\sum_{j=1}^{9} P4B_j^{GT} - P4B_i^{TIP} / \frac{1}{9}\sum_{j=1}^{9} P4B_j^{TIP} \right)$

Table 7-9, Summary of RMS (rd)[*] Differences between GT[**] and TIP Four-Bundle Powers and Readings

Cal. #	Date	Power %	P4B	TIP
1	19980406	29.2	1.8	1.6
2	19980406	55.8	2.5	2.8
3	19980407	83.3	2.7	3.1
18	19990401	92.3	2.5	3.1
	RMS	**<95.0**	**2.4**	**2.7**
4	19980413	99.7	2.6	3.3
5	19980423	99.6	2.7	3.4
6	19980430	99.6	2.4	3.2
7	19980518	99.4	2.5	3.1
8	19980525	99.5	2.8	3.4
9	19980605	99.5	2.6	3.2
10	19980616	99.5	2.5	3.2
11	19980723	99.8	2.5	3.2
12	19980831	99.8	2.9	3.2
13	19981006	99.7	2.6	3.0
14	19981112	99.5	2.9	3.5
15	19981217	99.5	2.5	3.0
16	19990121	99.4	2.9	3.5
17	19990225	98.7	2.9	3.4
	RMS	**≥95.0**	**2.7**	**3.3**
	RMS	**All**	**2.6**	**3.2**

[*] $RMS^{(k)} = \sqrt{\frac{1}{18}\sum_{i=1}^{18}\delta_i^{(k)2}}$

[**] GT readings have been converted to equivalent fission detector readings.

Figure 7-15, Comparison of GT with TIP Readings for RSTK-01

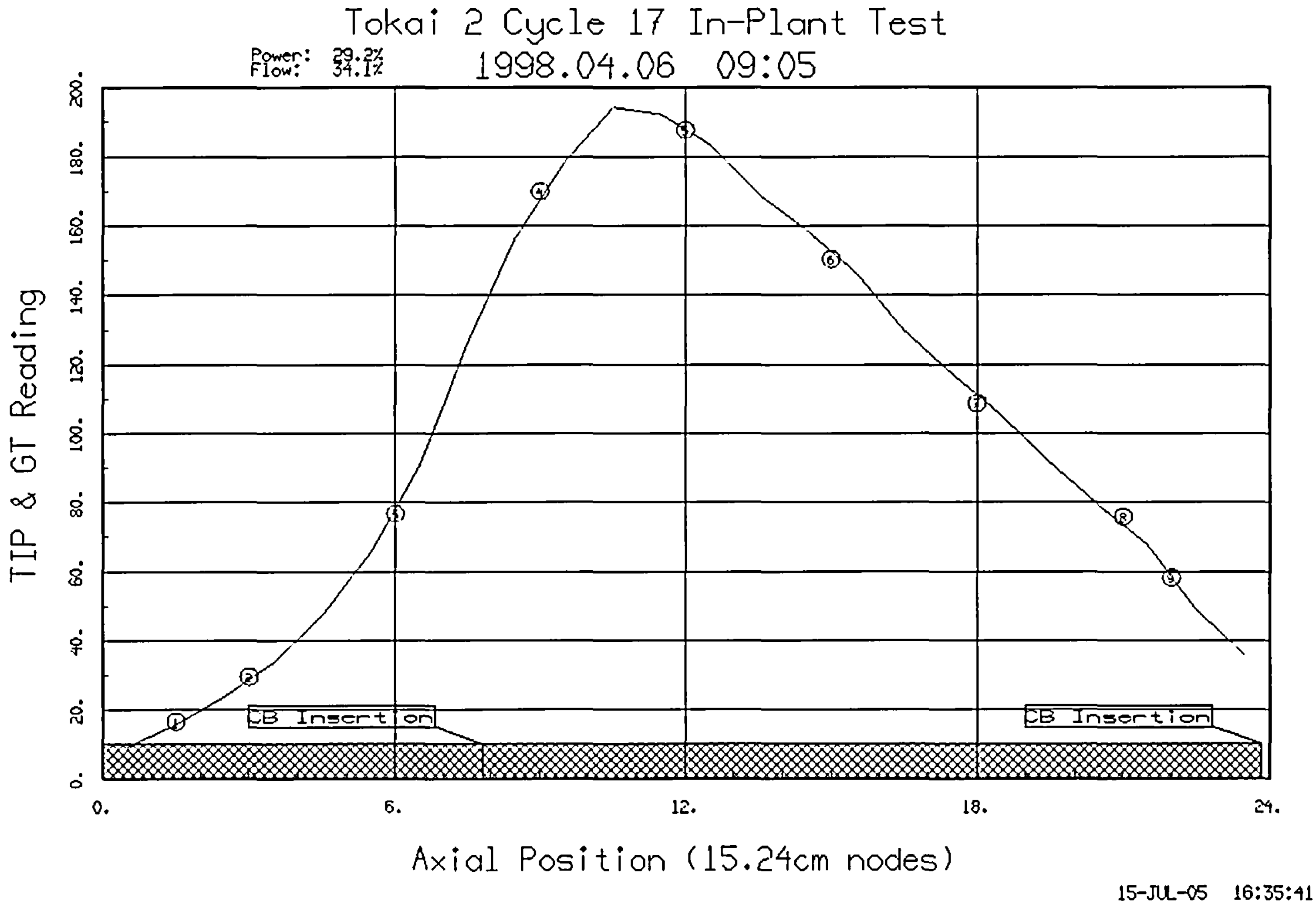


Figure 7-16, Comparison of GT with TIP Readings for RSTK-02

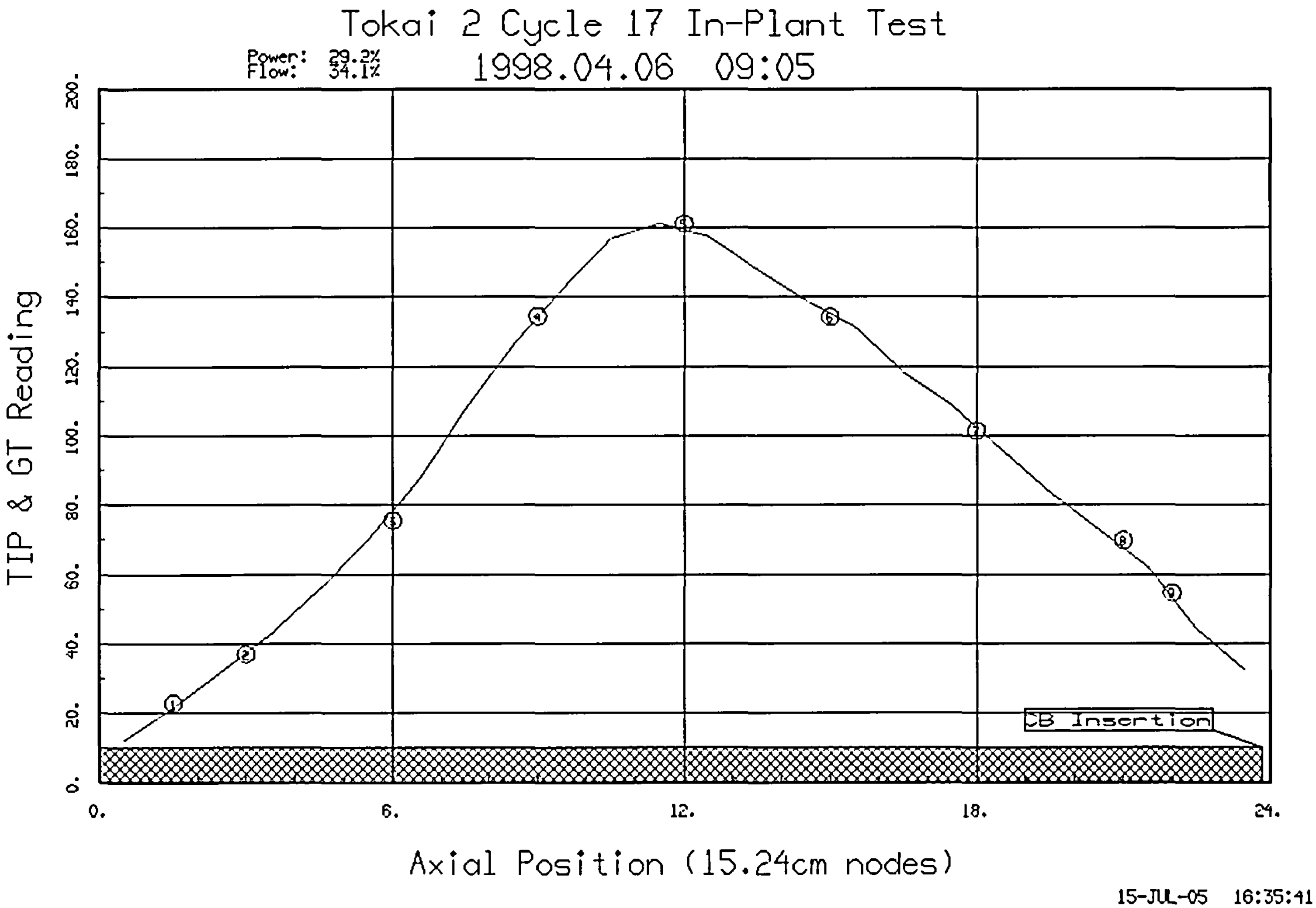


Figure 7-17, Comparison of GT with TIP Readings for RSTK-01

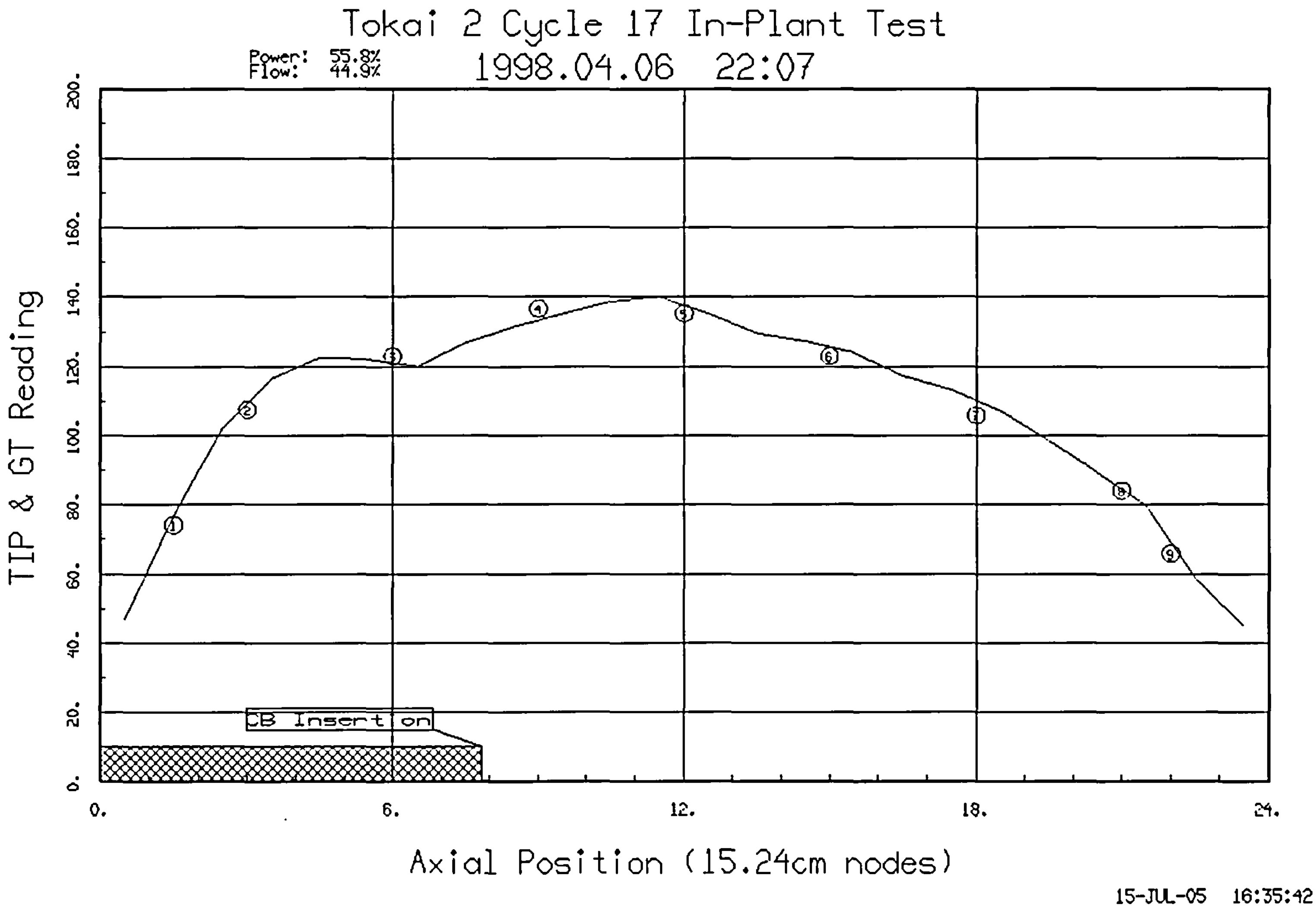


Figure 7-18, Comparison of GT with TIP Readings for RSTK-02

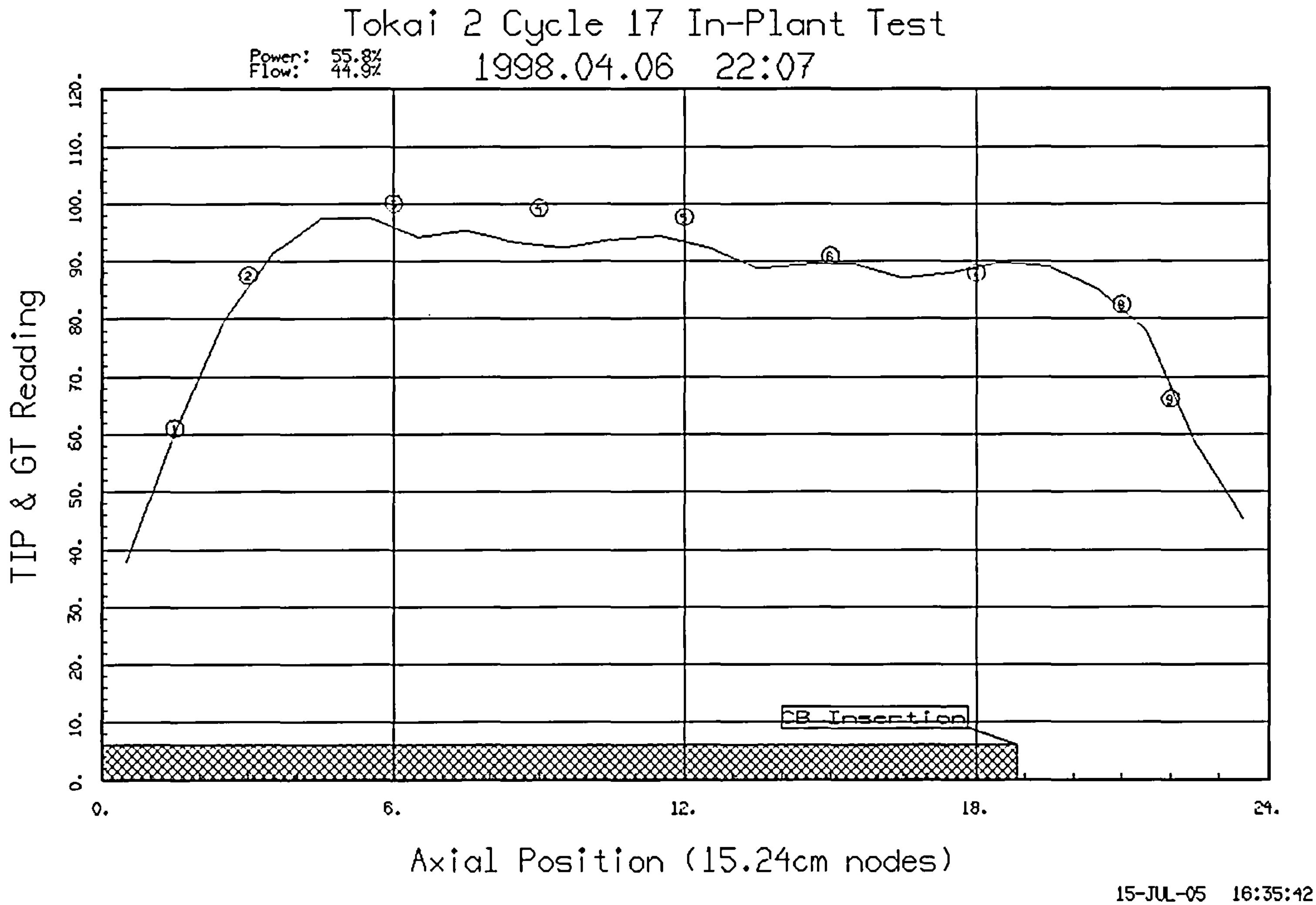


Figure 7-19, Comparison of GT with TIP Readings for RSTK-01

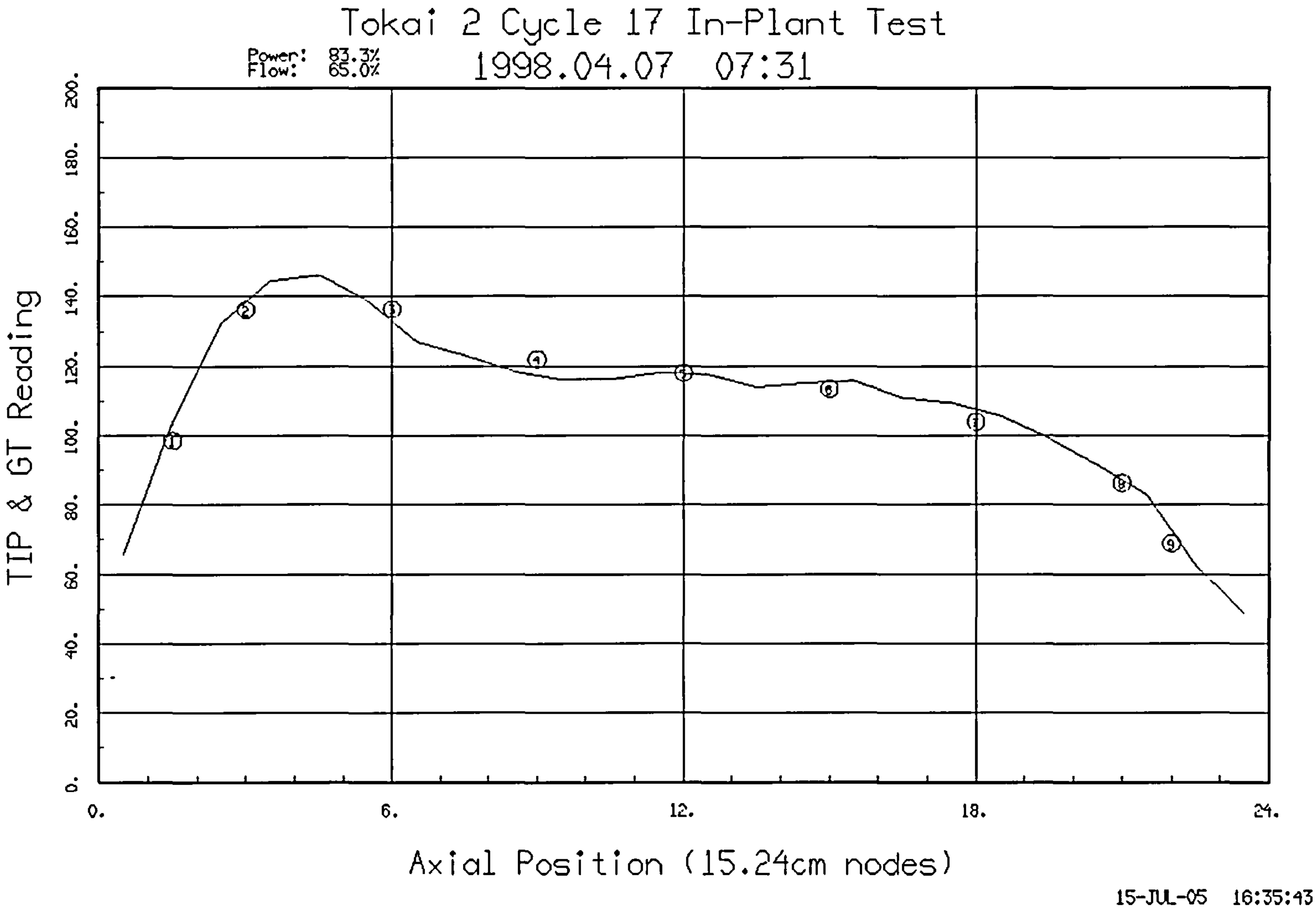


Figure 7-20, Comparison of GT with TIP Readings for RSTK-02

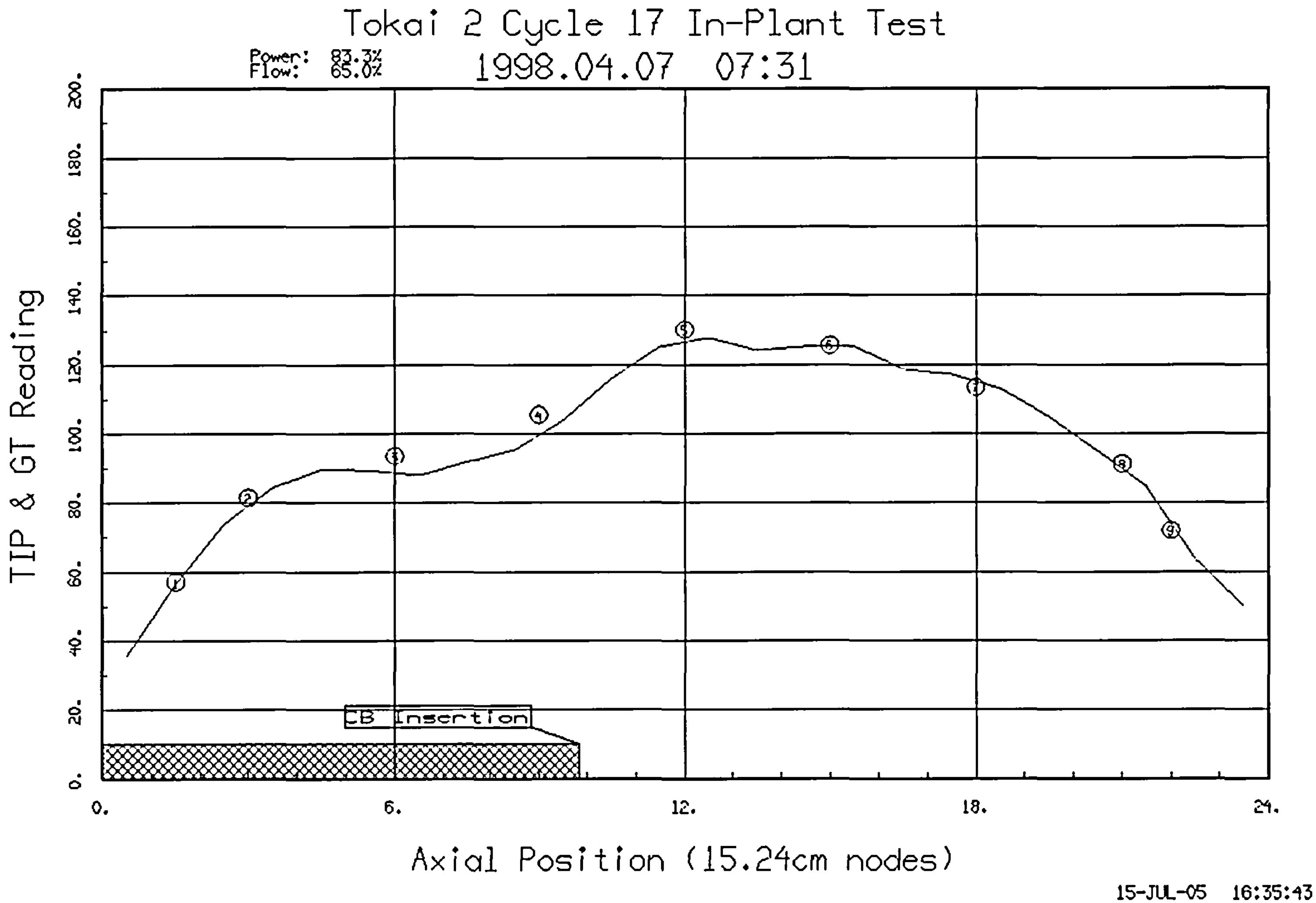


Figure 7-21, Comparison of GT with TIP Readings for RSTK-01

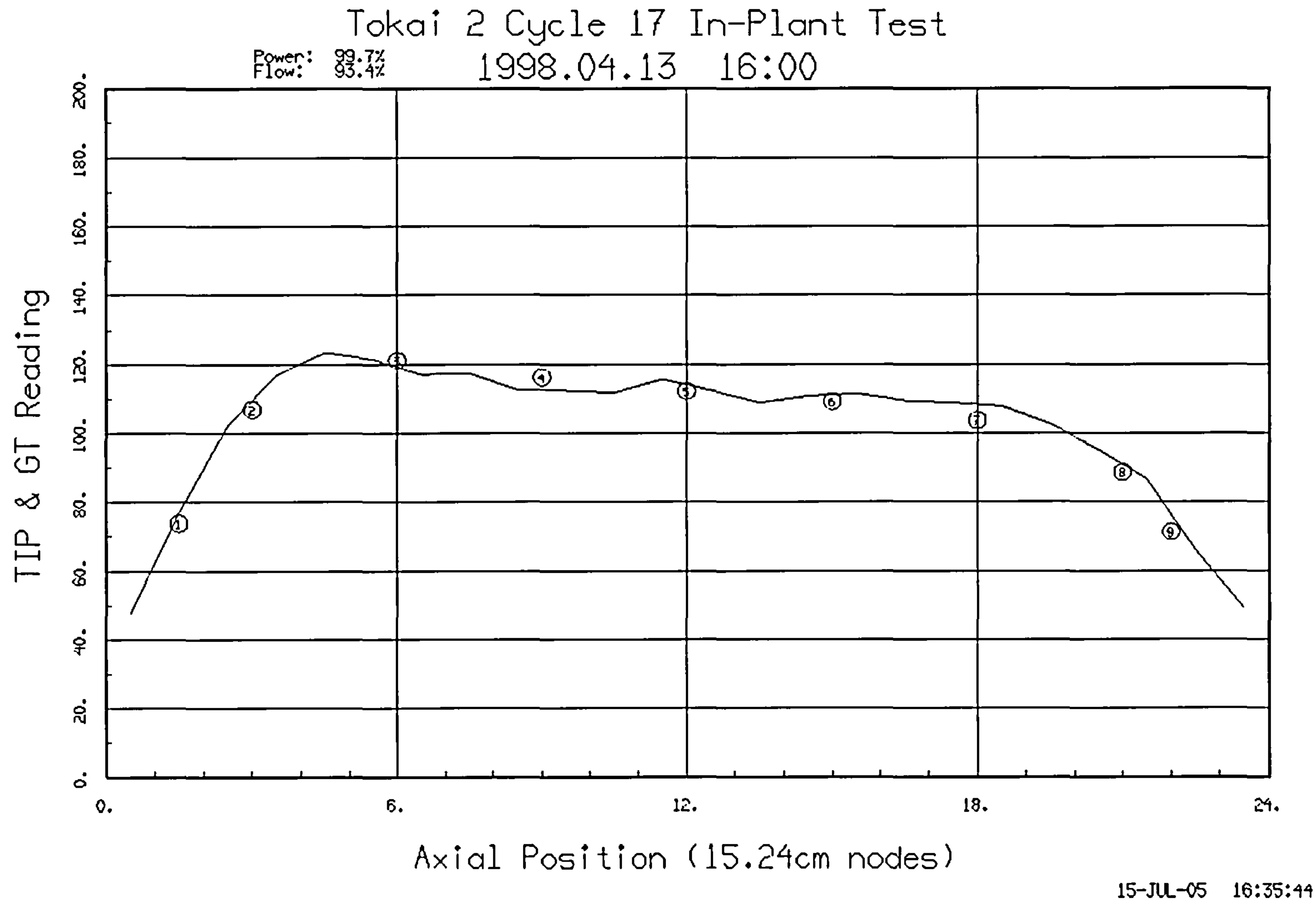


Figure 7-22, Comparison of GT with TIP Readings for RSTK-02

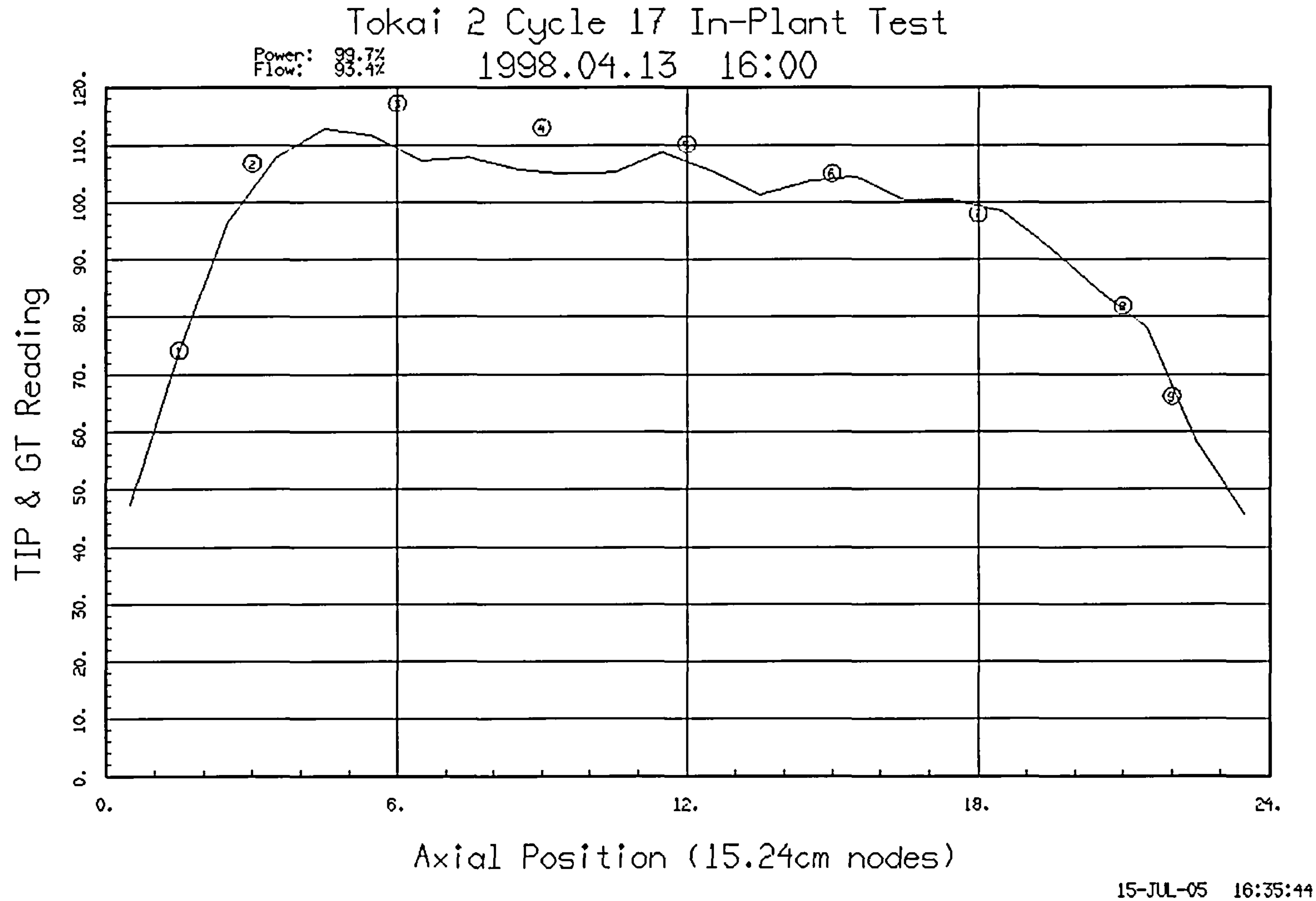


Figure 7-23, Comparison of GT with TIP Readings for RSTK-01

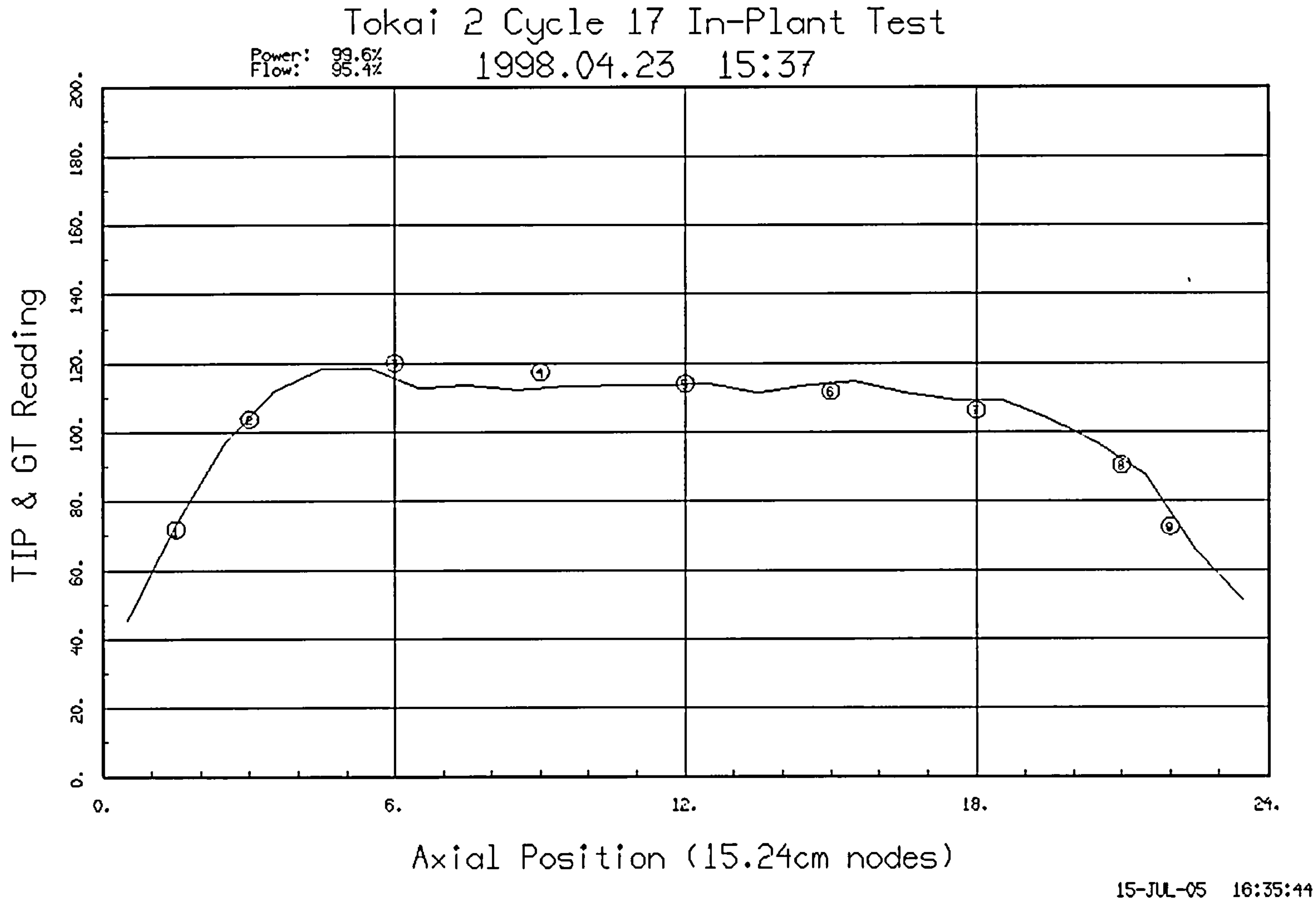


Figure 7-24, Comparison of GT with TIP Readings for RSTK-02

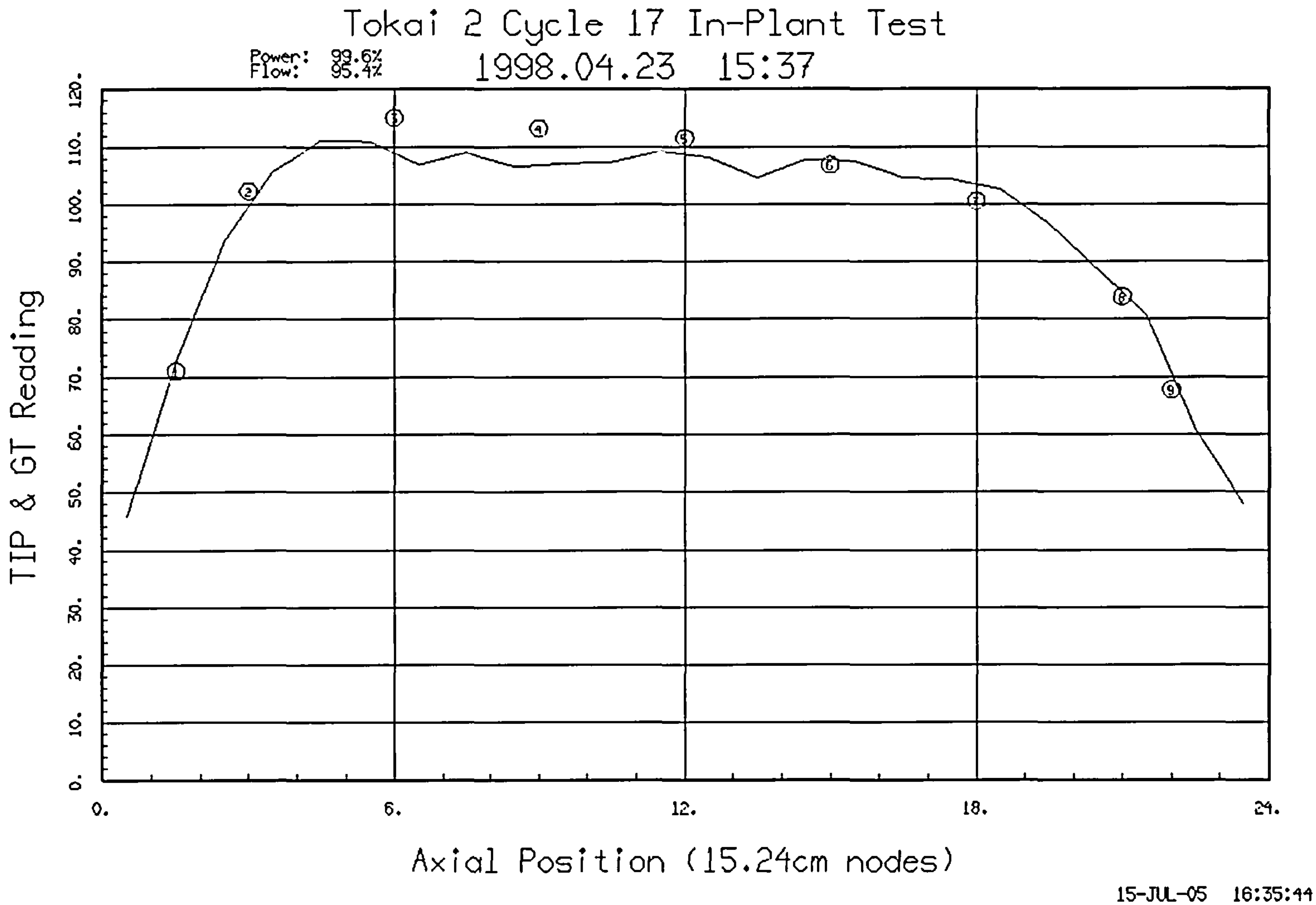


Figure 7-25, Comparison of GT with TIP Readings for RSTK-01

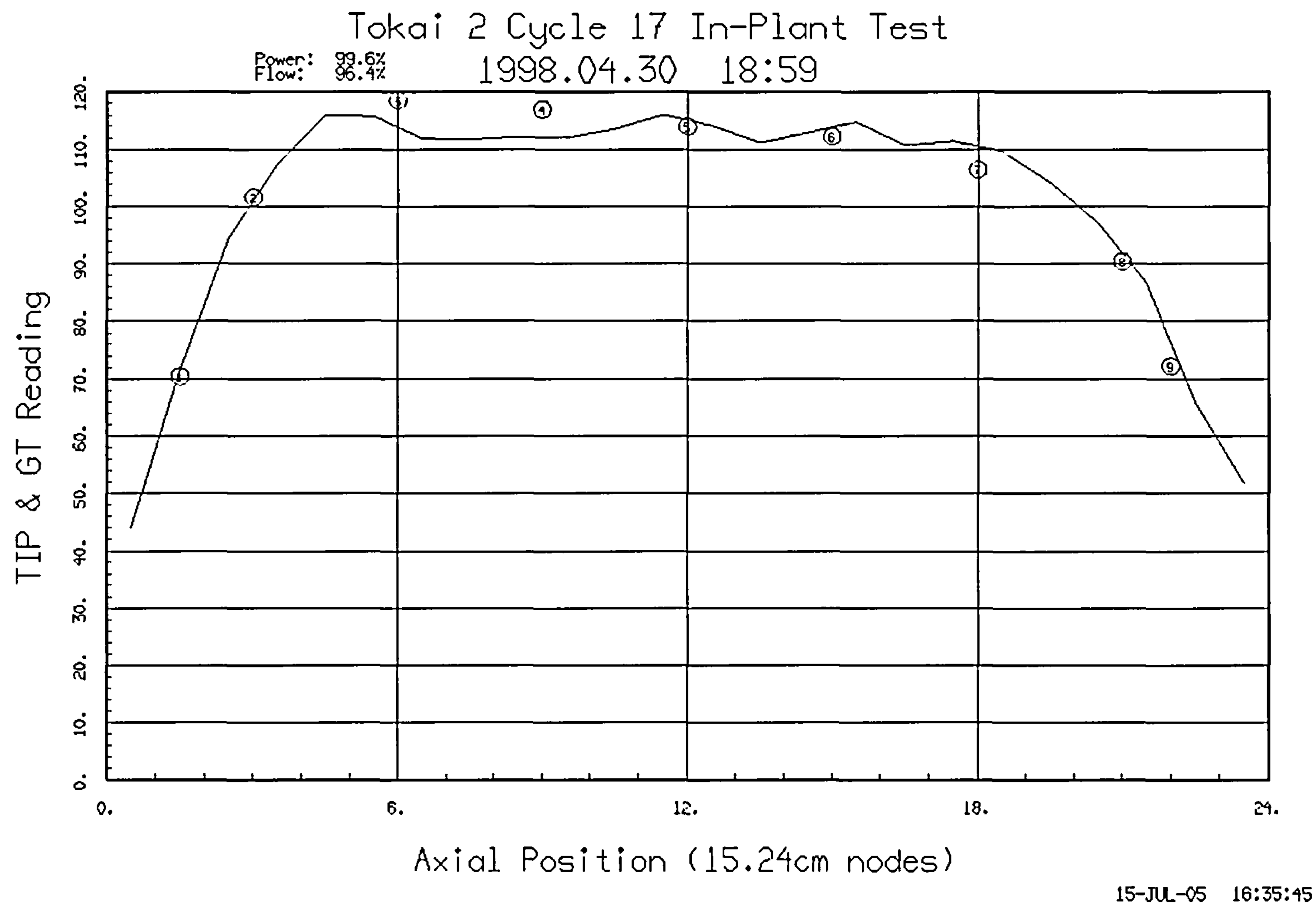


Figure 7-26, Comparison of GT with TIP Readings for RSTK-02

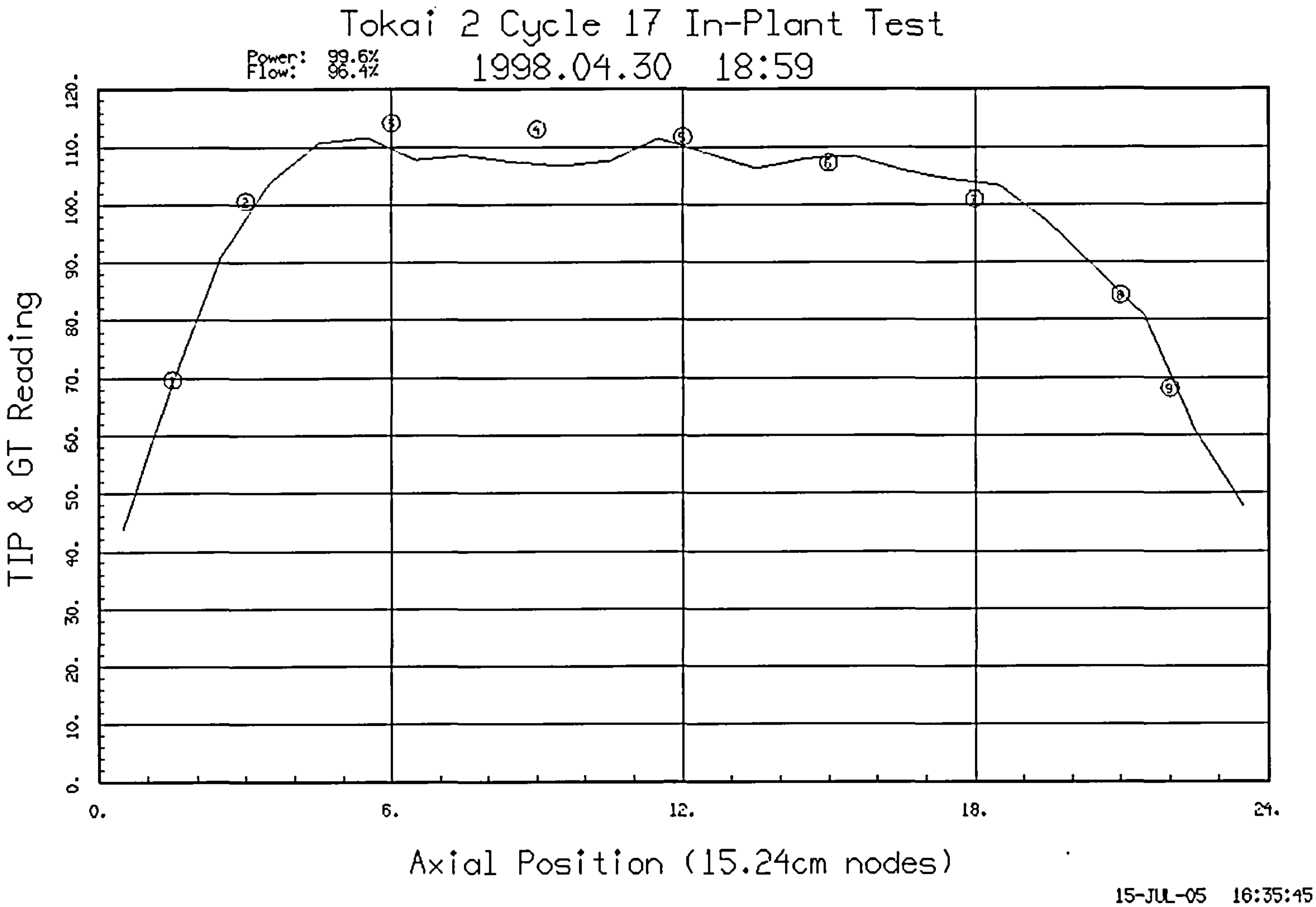


Figure 7-27, Comparison of GT with TIP Readings for RSTK-01

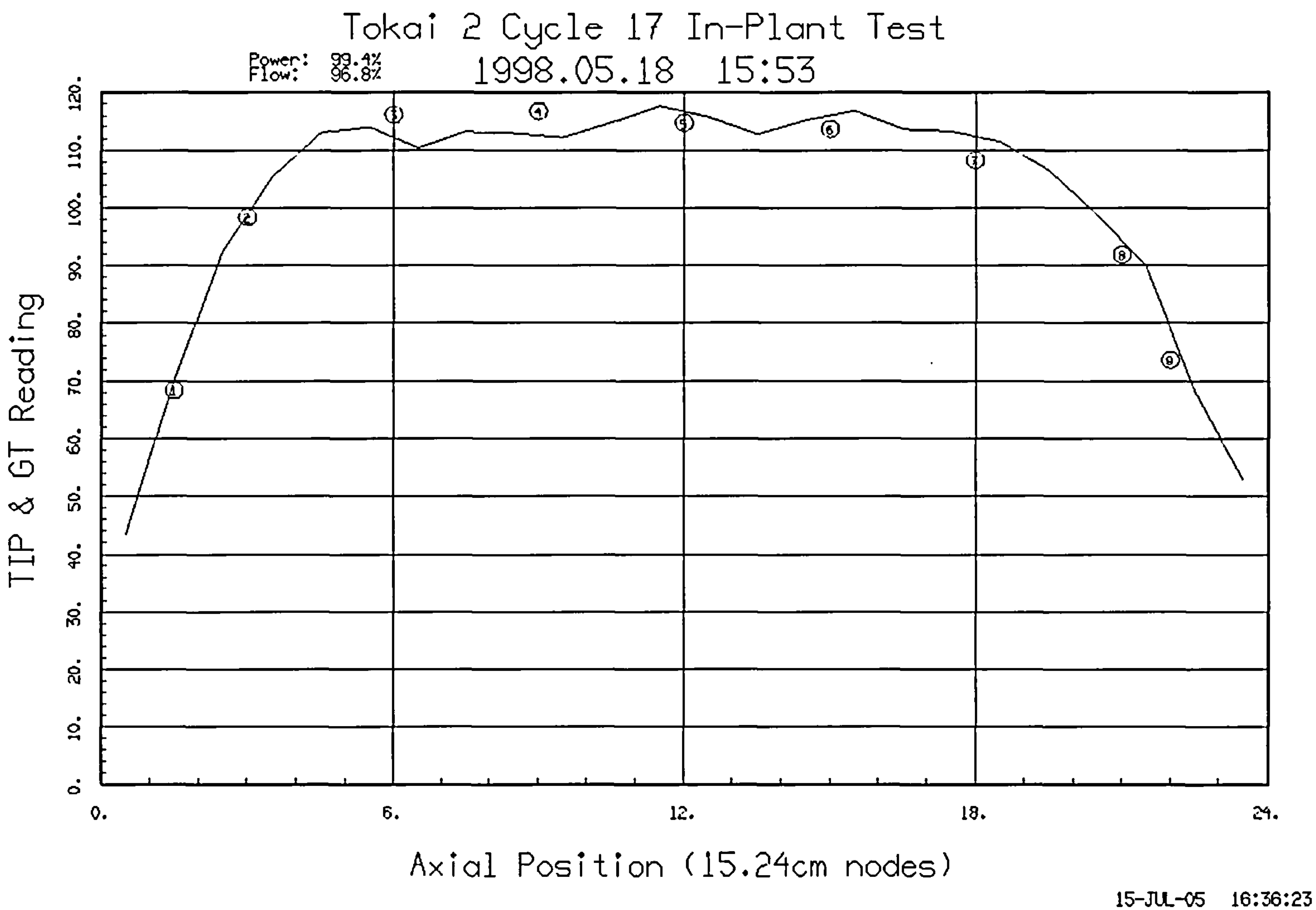


Figure 7-28, Comparison of GT with TIP Readings for RSTK-02

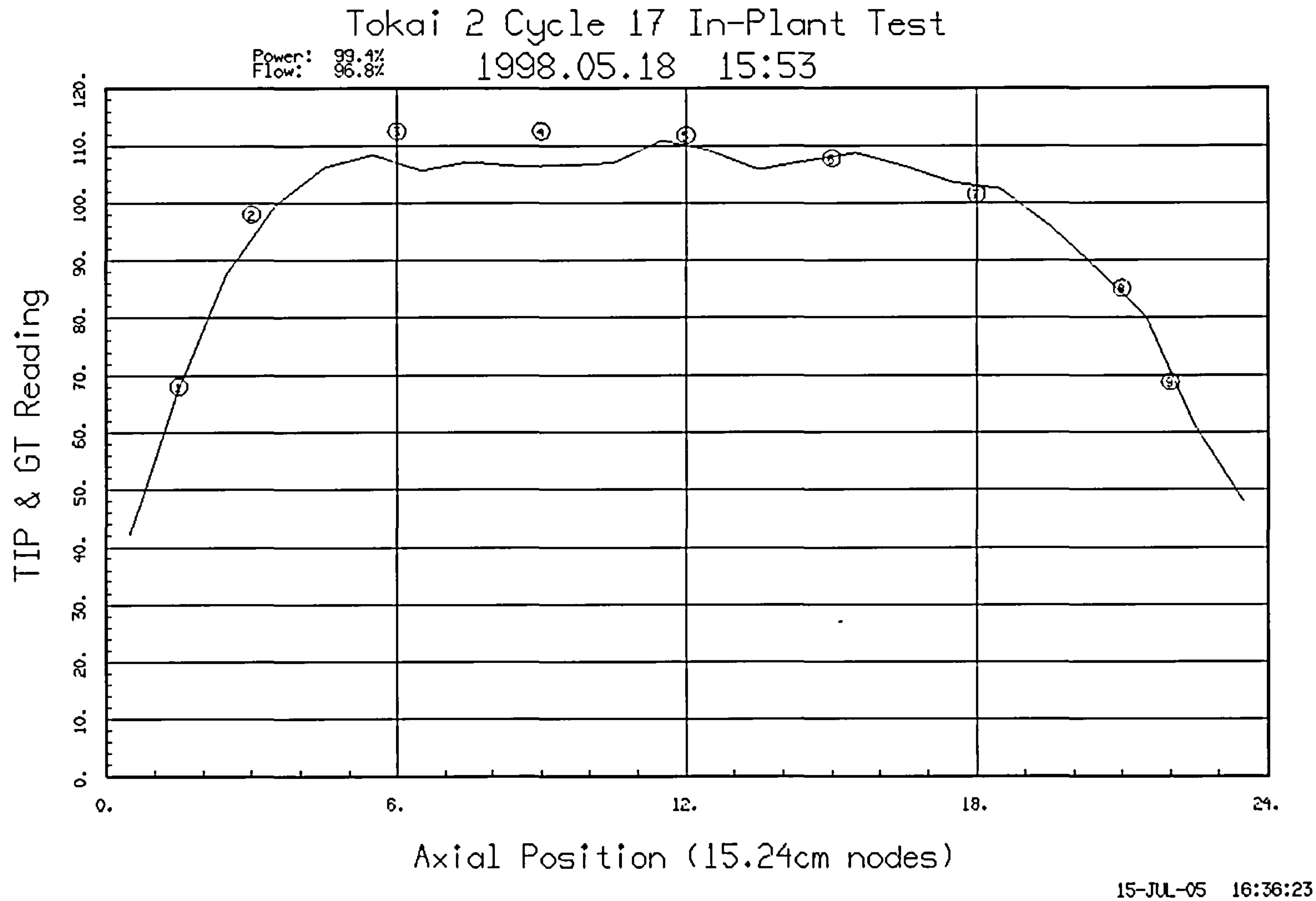


Figure 7-29, Comparison of GT with TIP Readings for RSTK-01

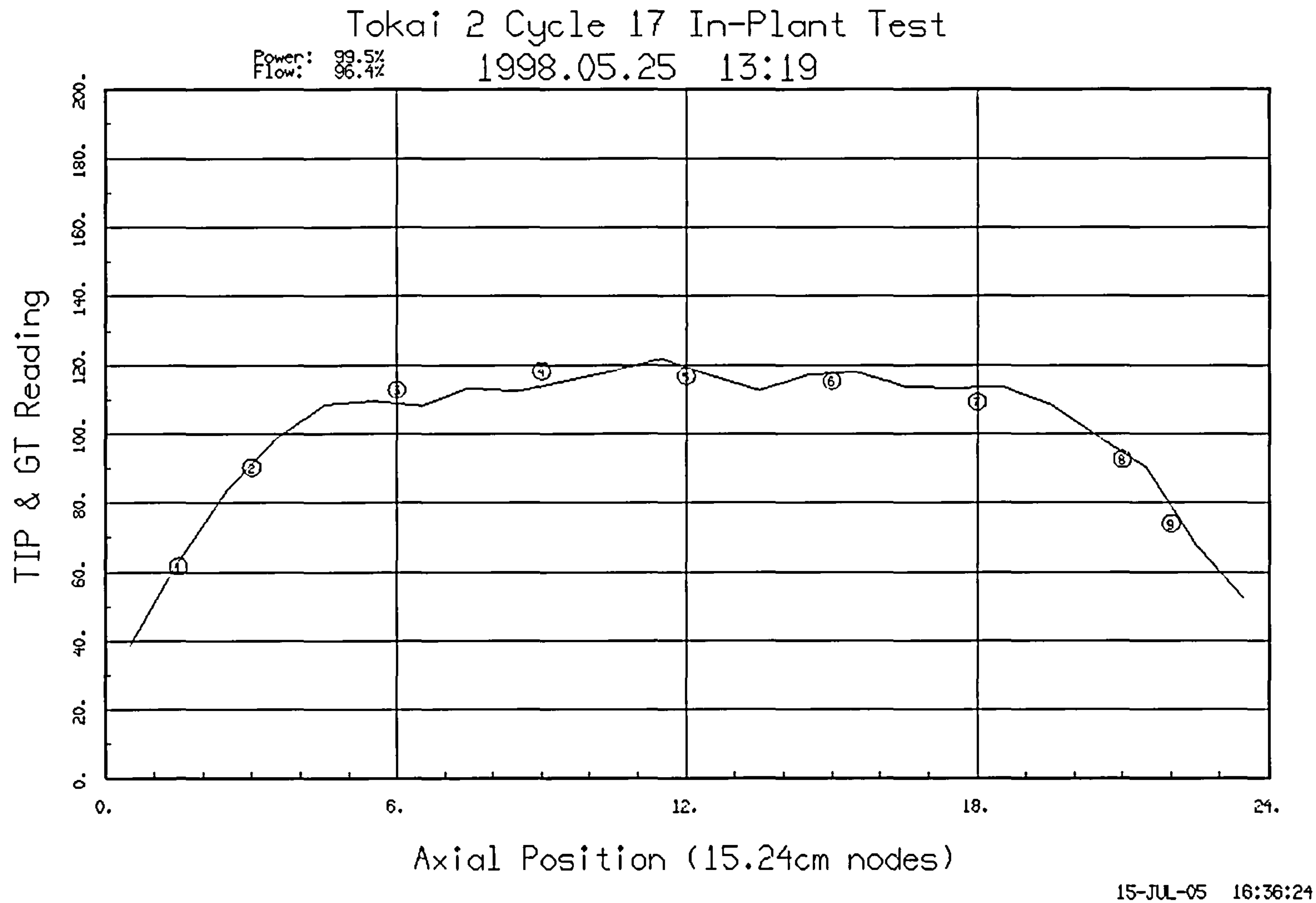


Figure 7-30, Comparison of GT with TIP Readings for RSTK-02

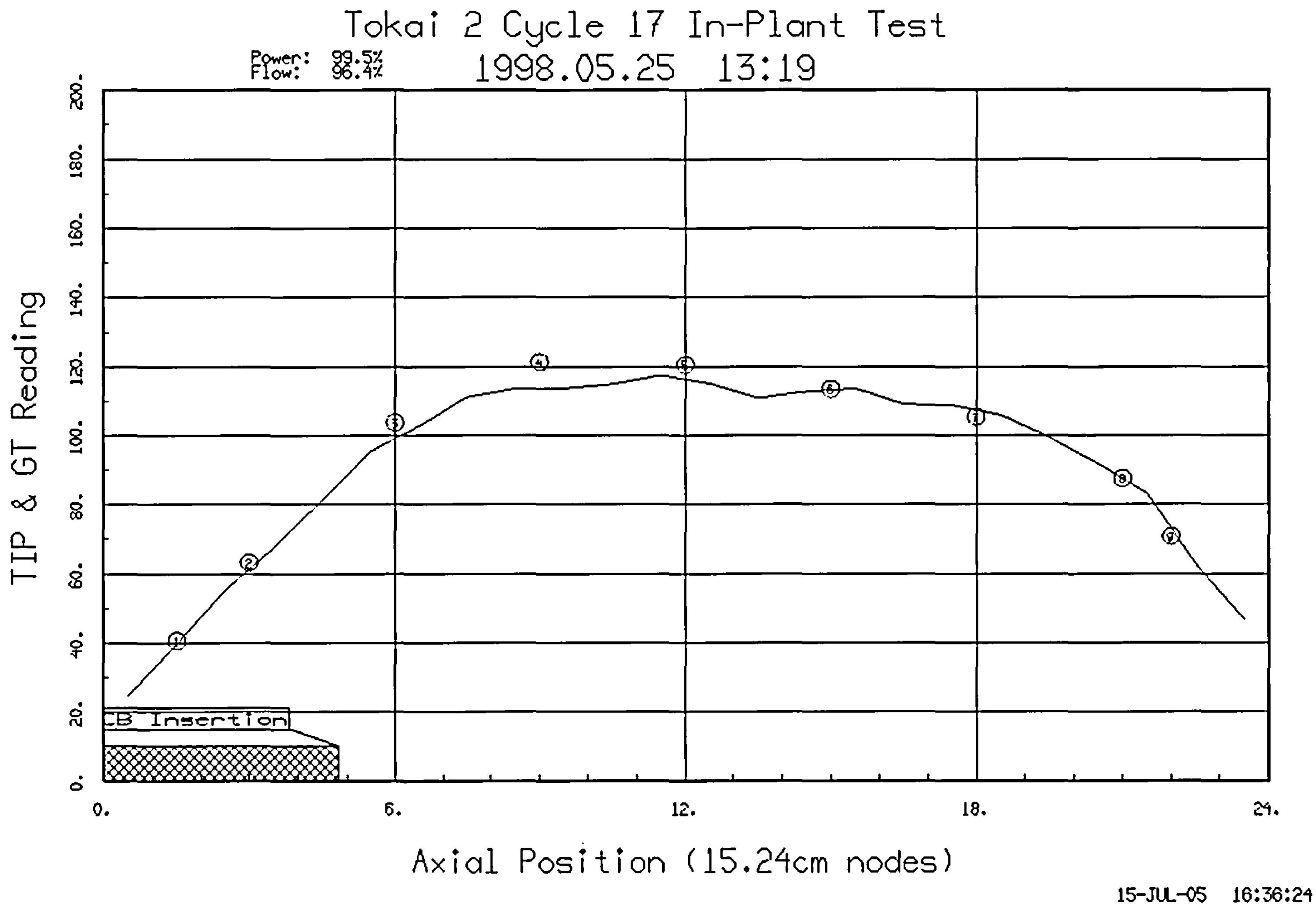


Figure 7-31, Comparison of GT with TIP Readings for RSTK-01

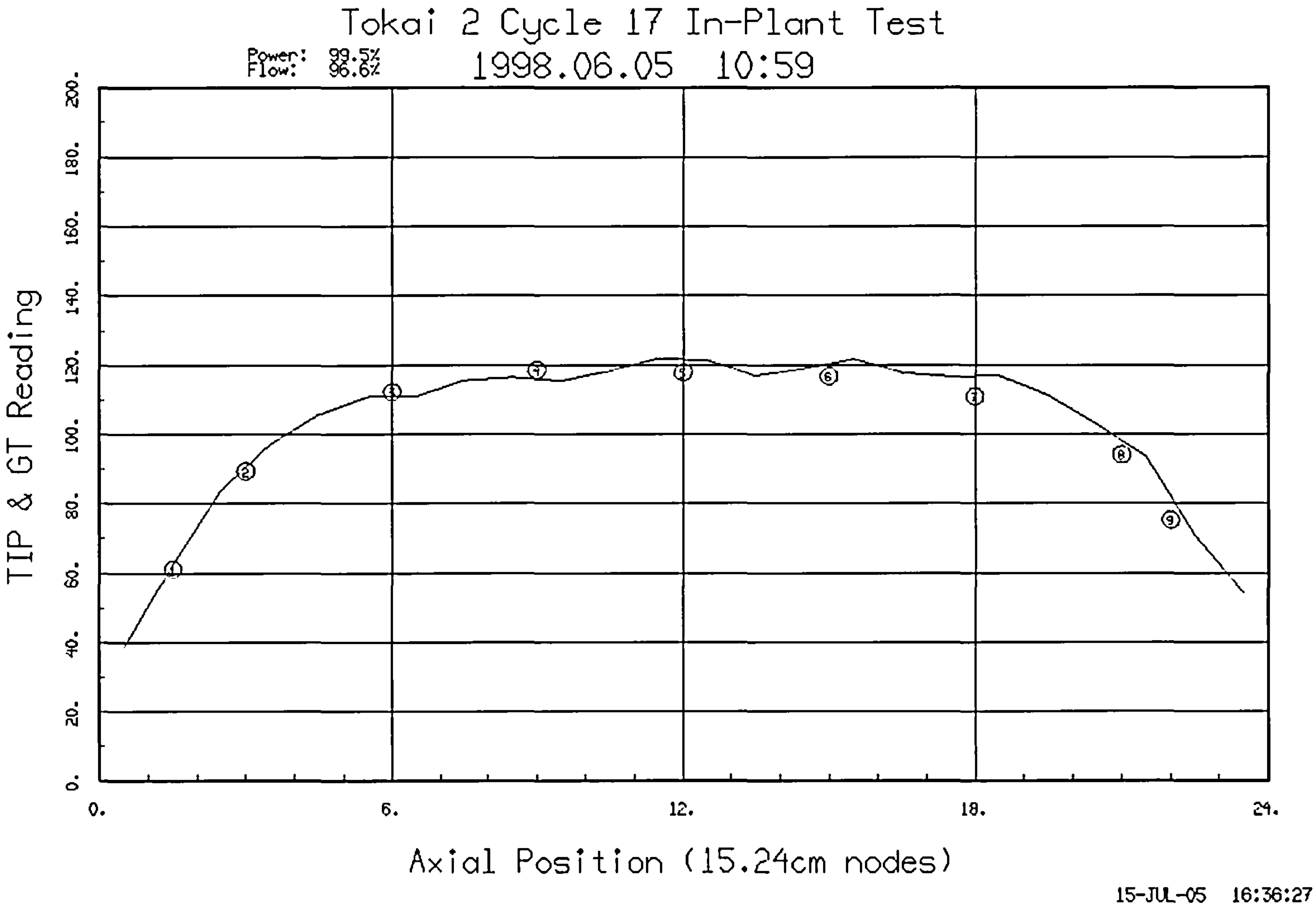


Figure 7-32, Comparison of GT with TIP Readings for RSTK-02

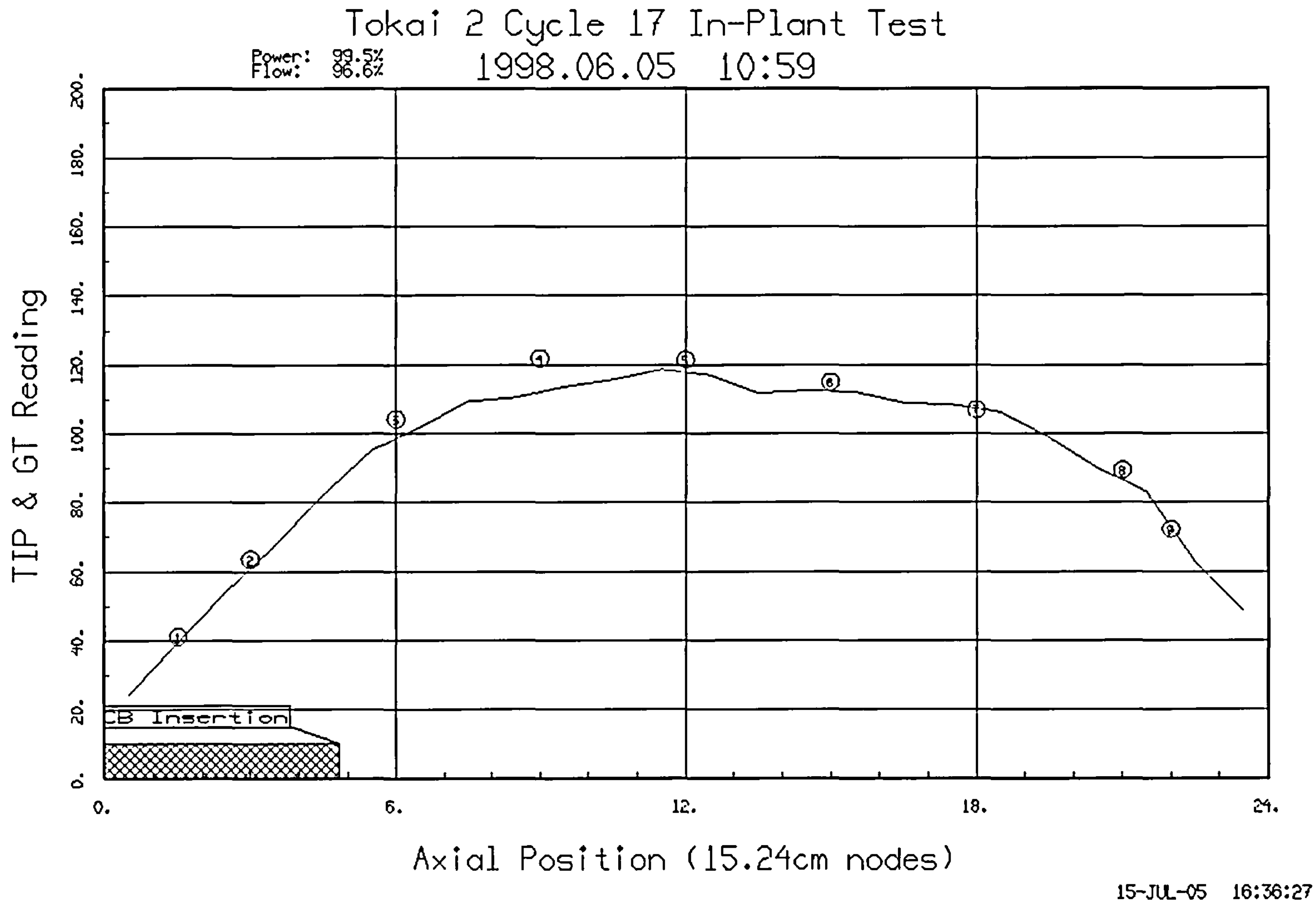


Figure 7-33, Comparison of GT with TIP Readings for RSTK-01

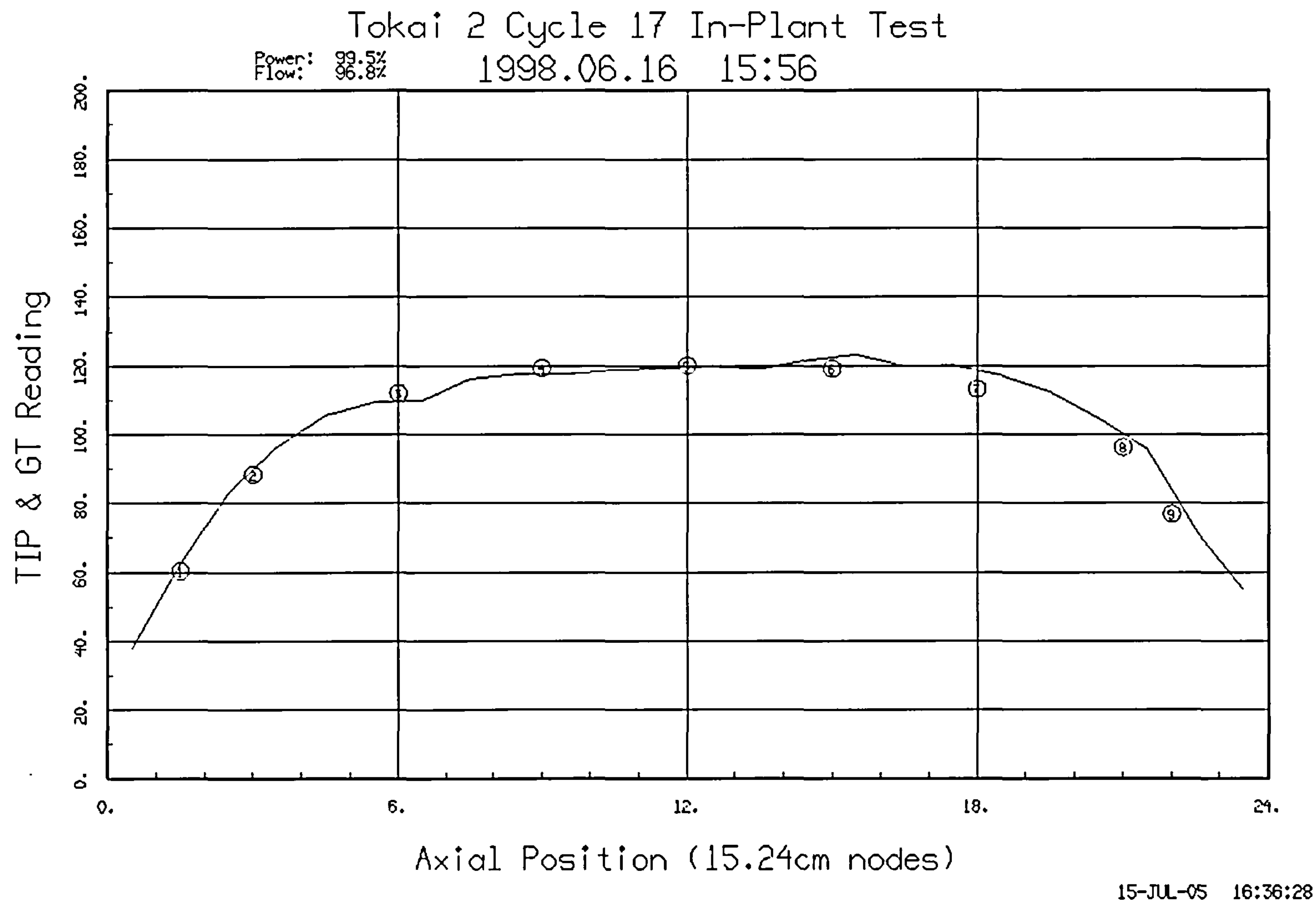


Figure 7-34, Comparison of GT with TIP Readings for RSTK-02

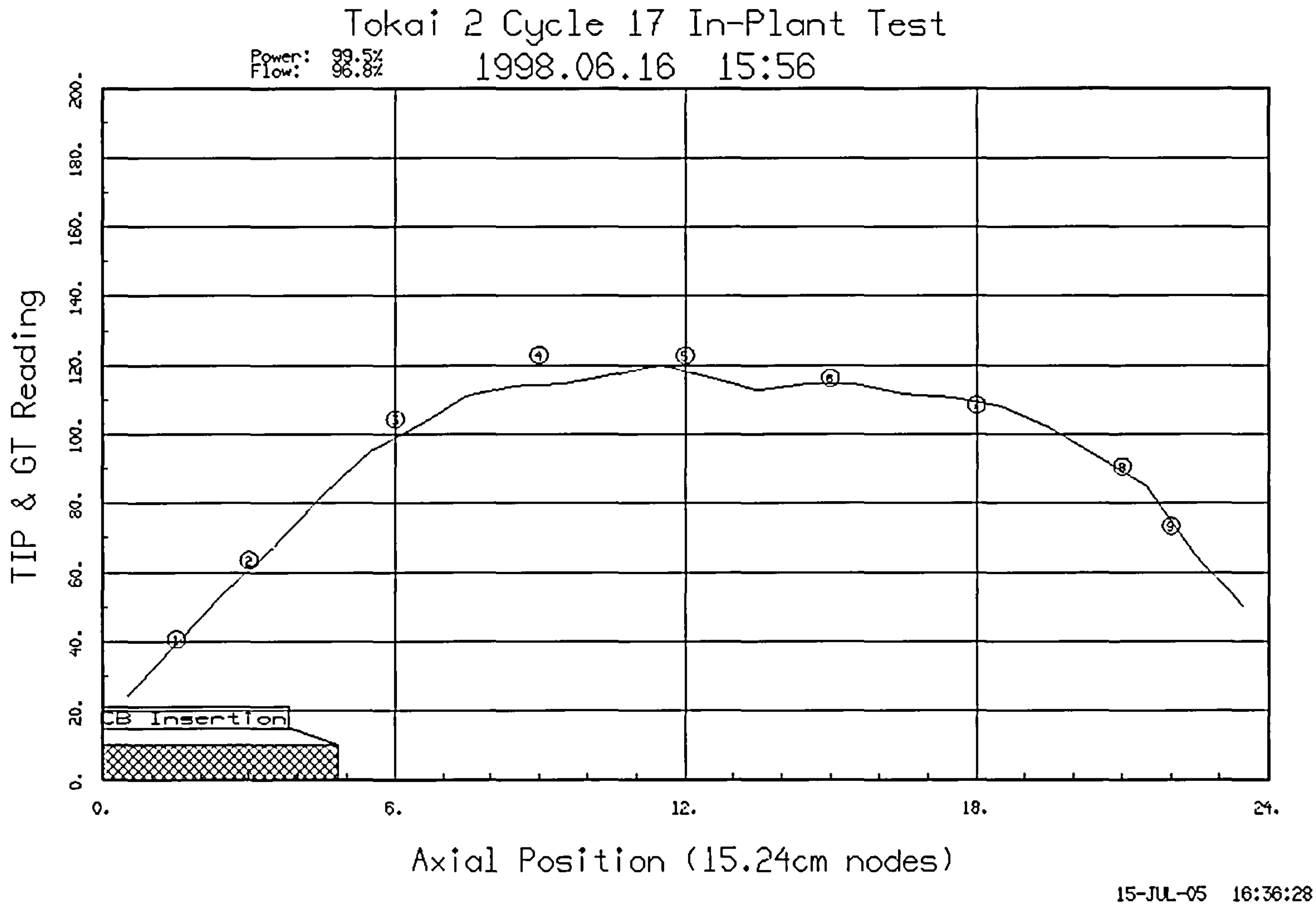


Figure 7-35, Comparison of GT with TIP Readings for RSTK-01

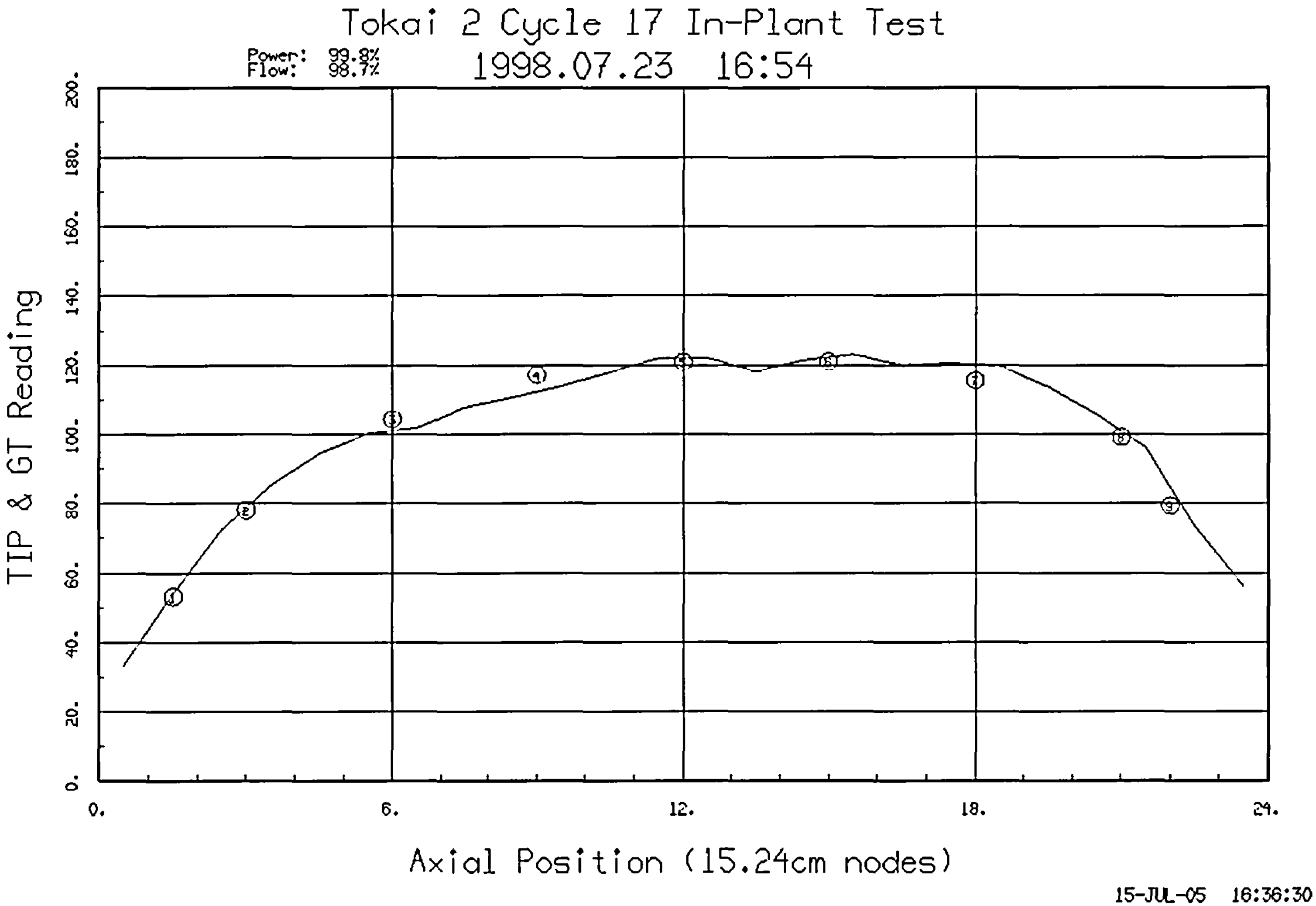


Figure 7-36, Comparison of GT with TIP Readings for RSTK-02

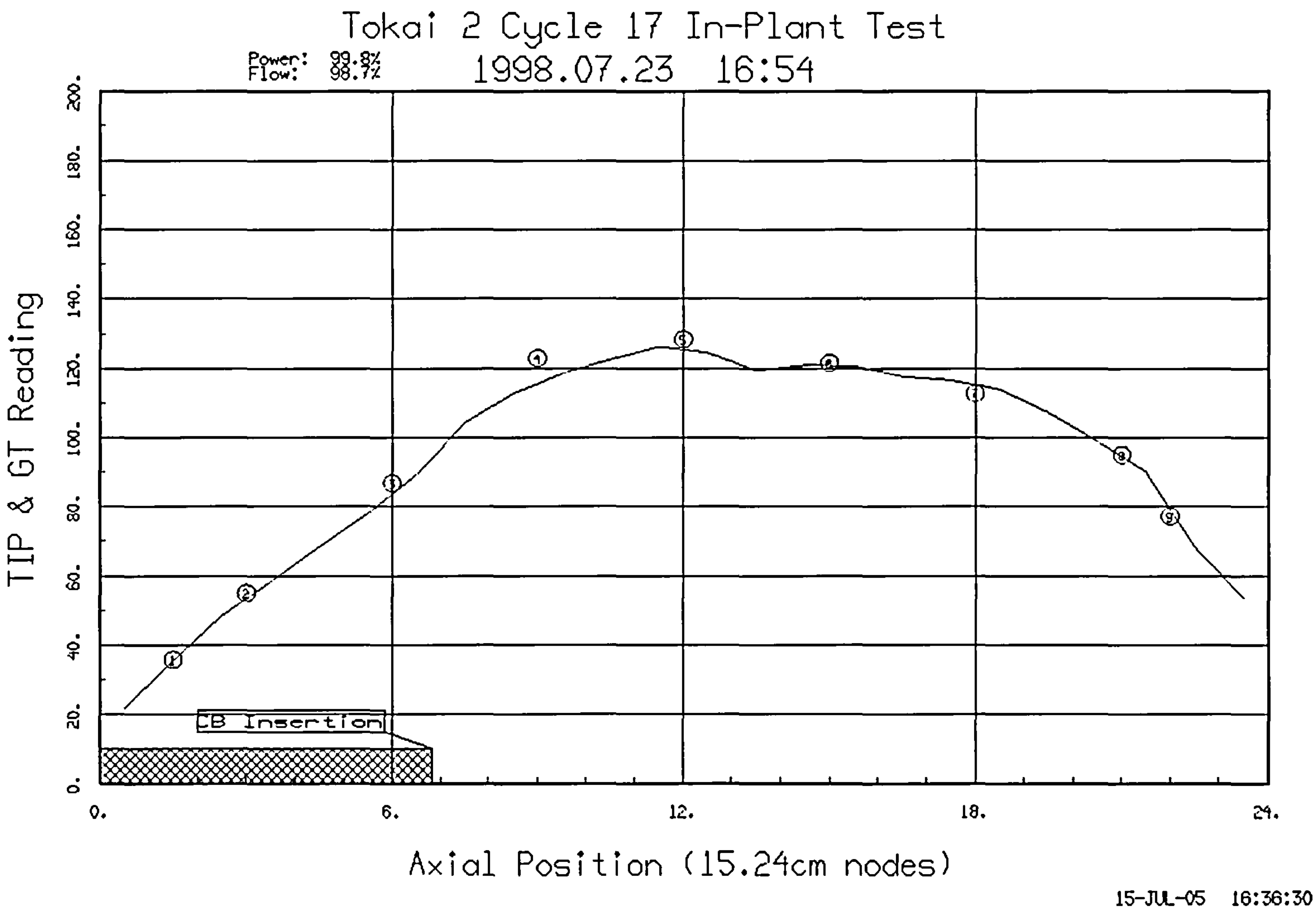


Figure 7-37, Comparison of GT with TIP Readings for RSTK-01

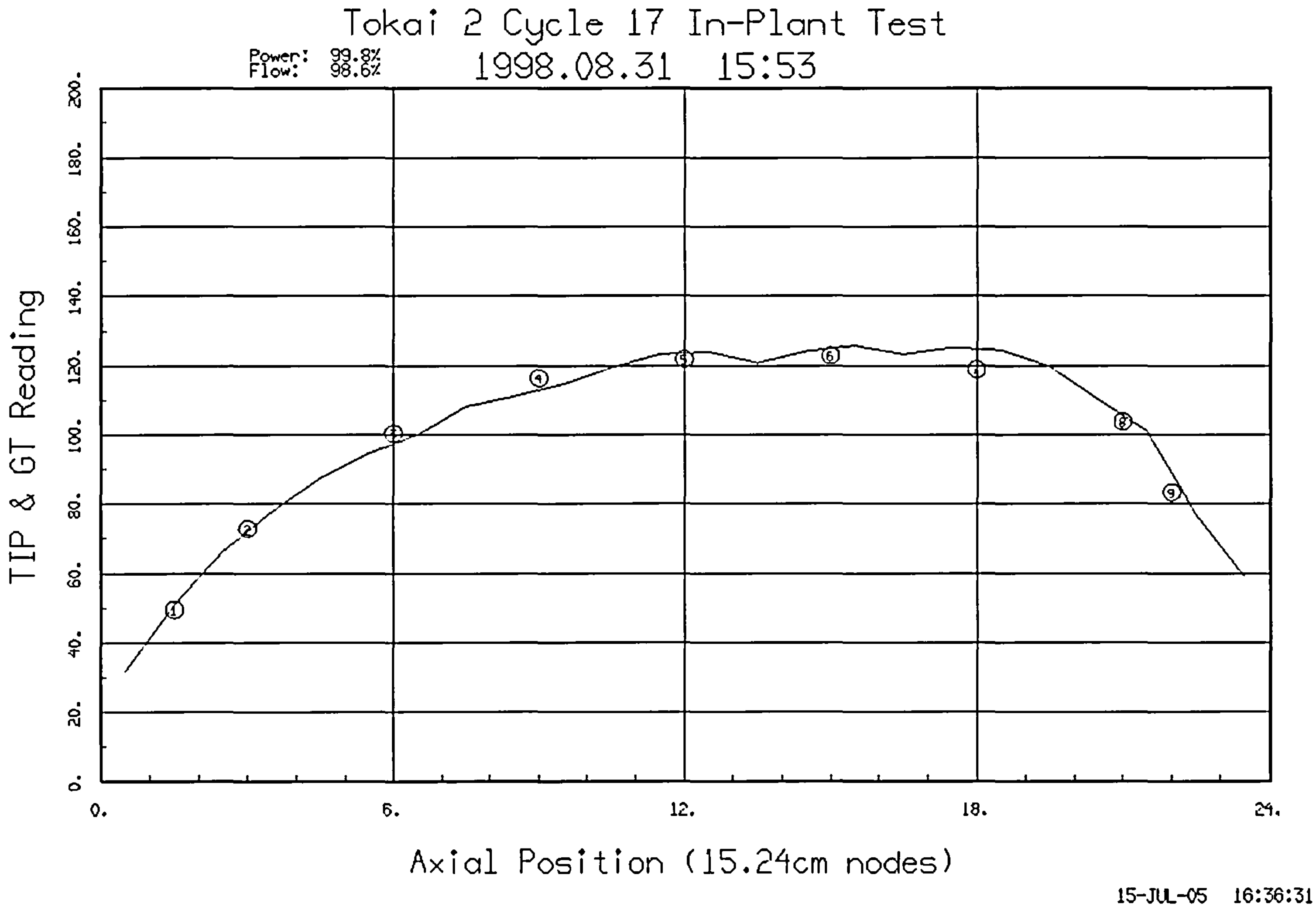


Figure 7-38, Comparison of GT with TIP Readings for RSTK-02

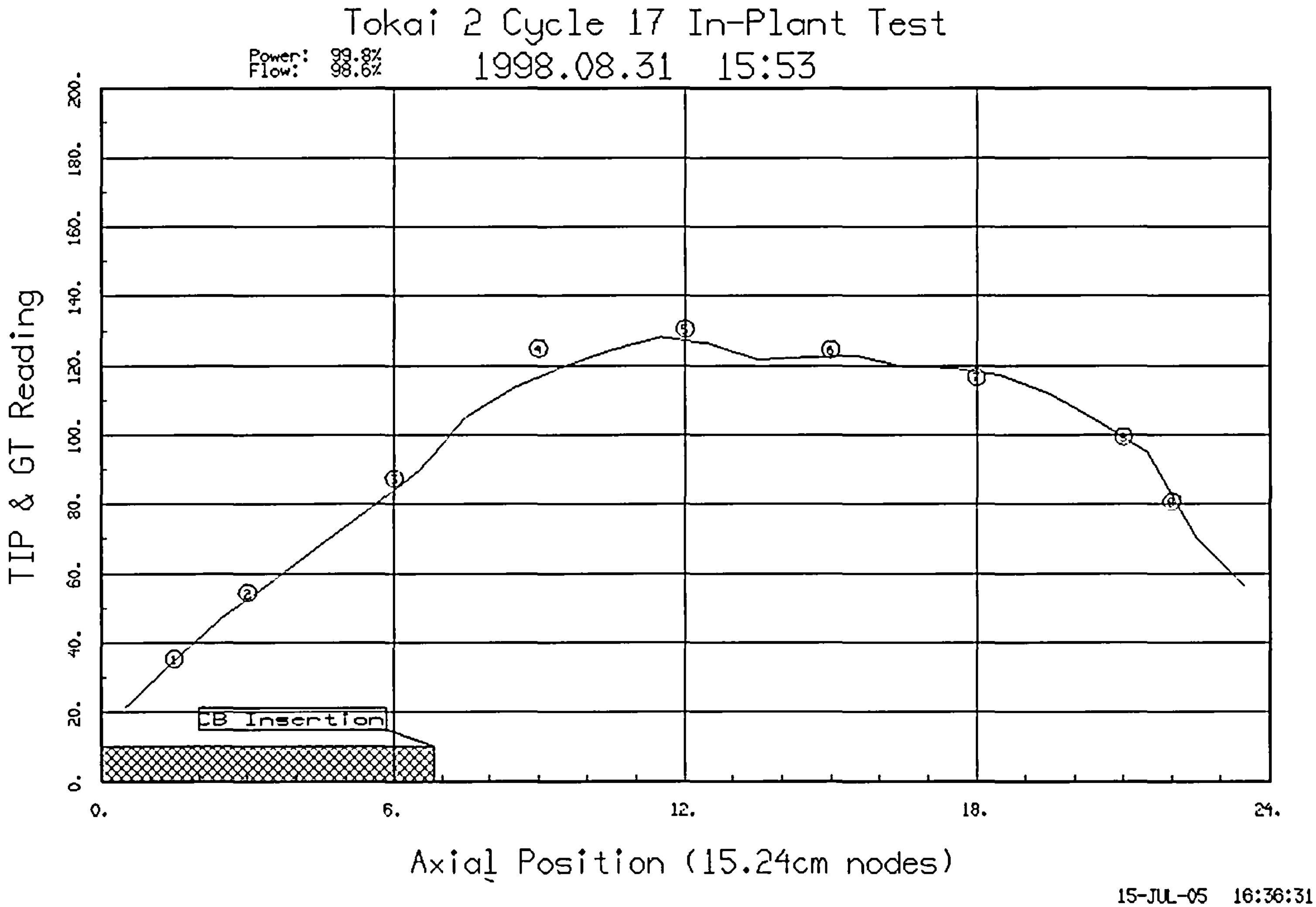


Figure 7-39, Comparison of GT with TIP Readings for RSTK-01

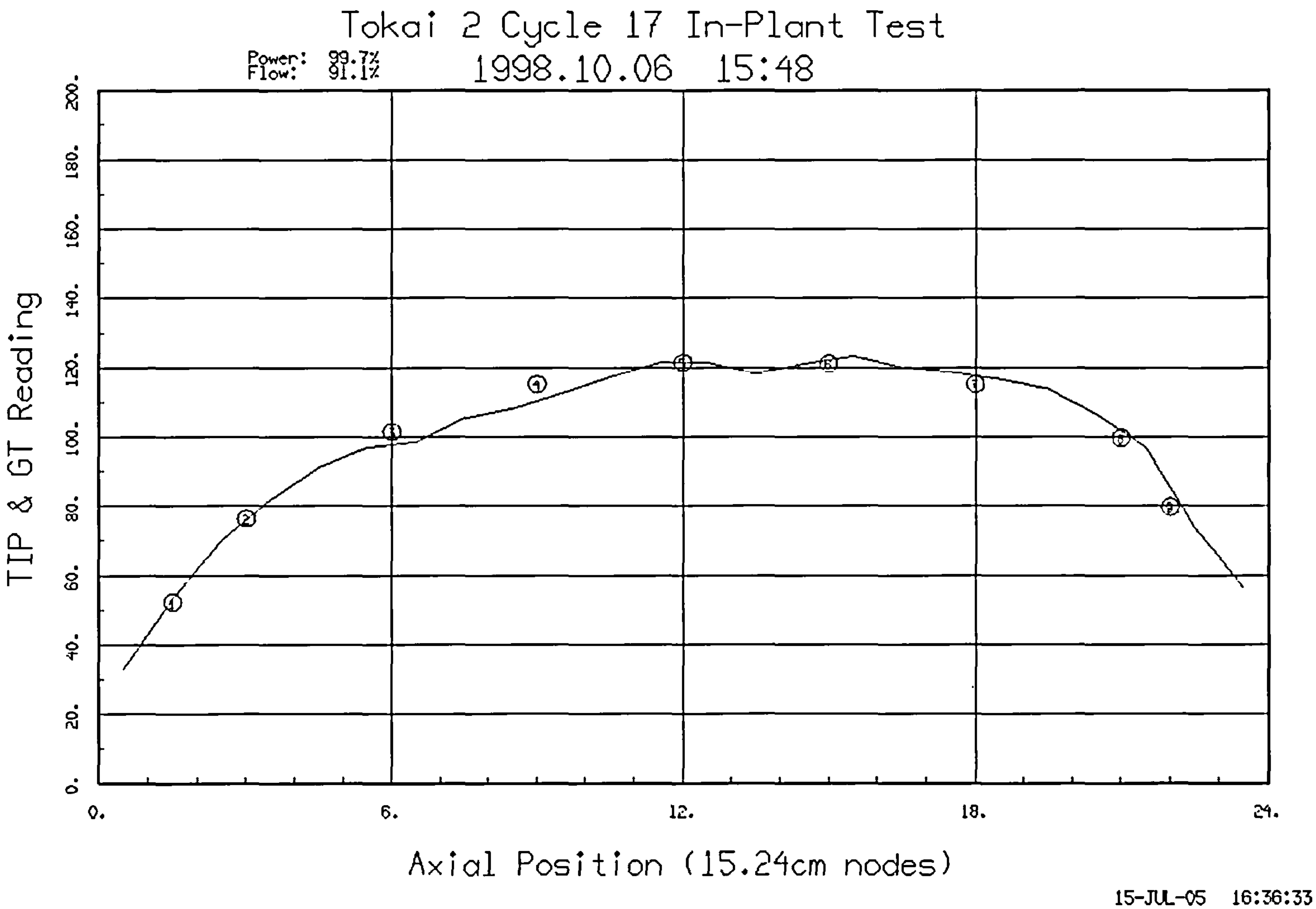


Figure 7-40, Comparison of GT with TIP Readings for RSTK-02

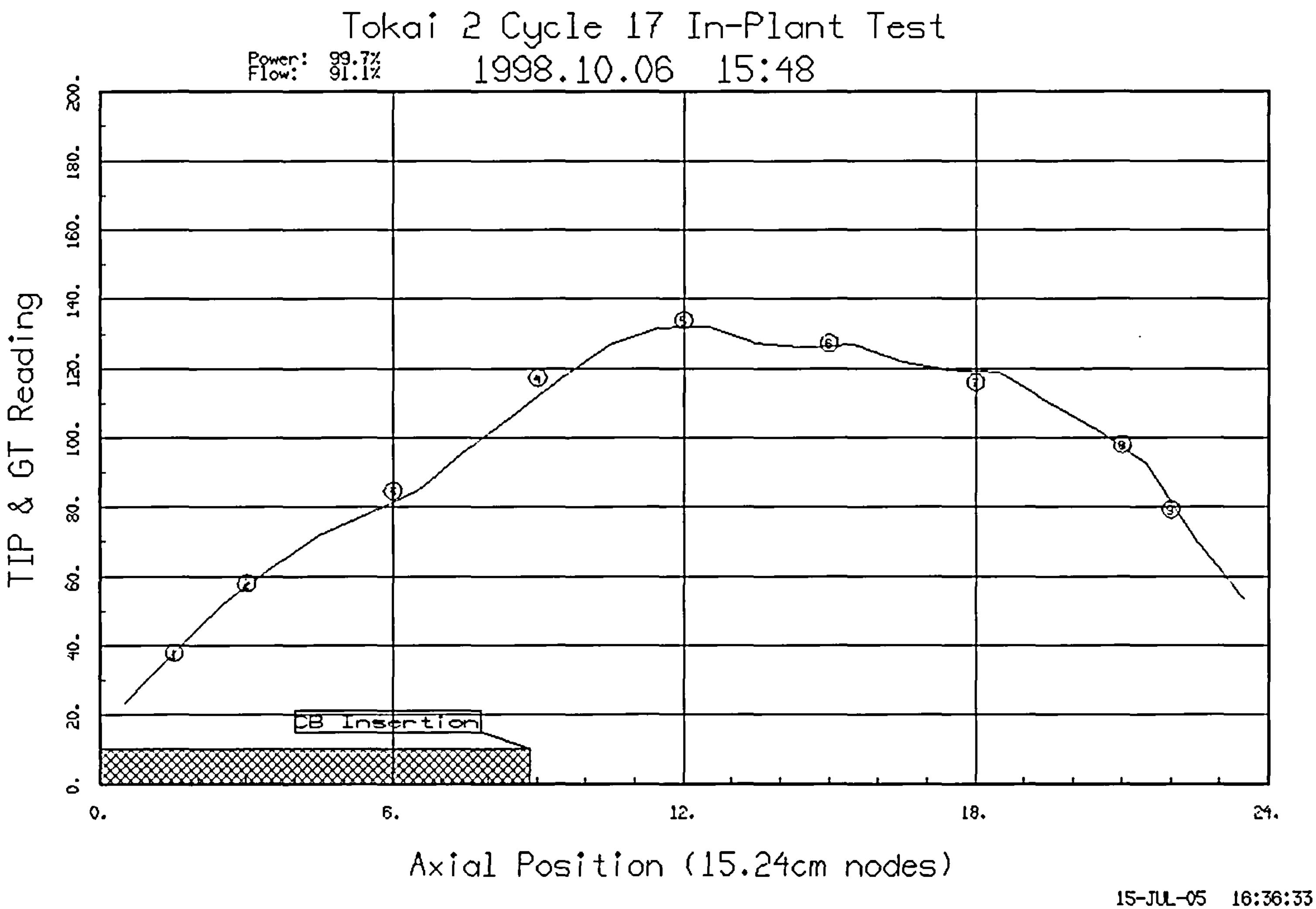


Figure 7-41, Comparison of GT with TIP Readings for RSTK-01

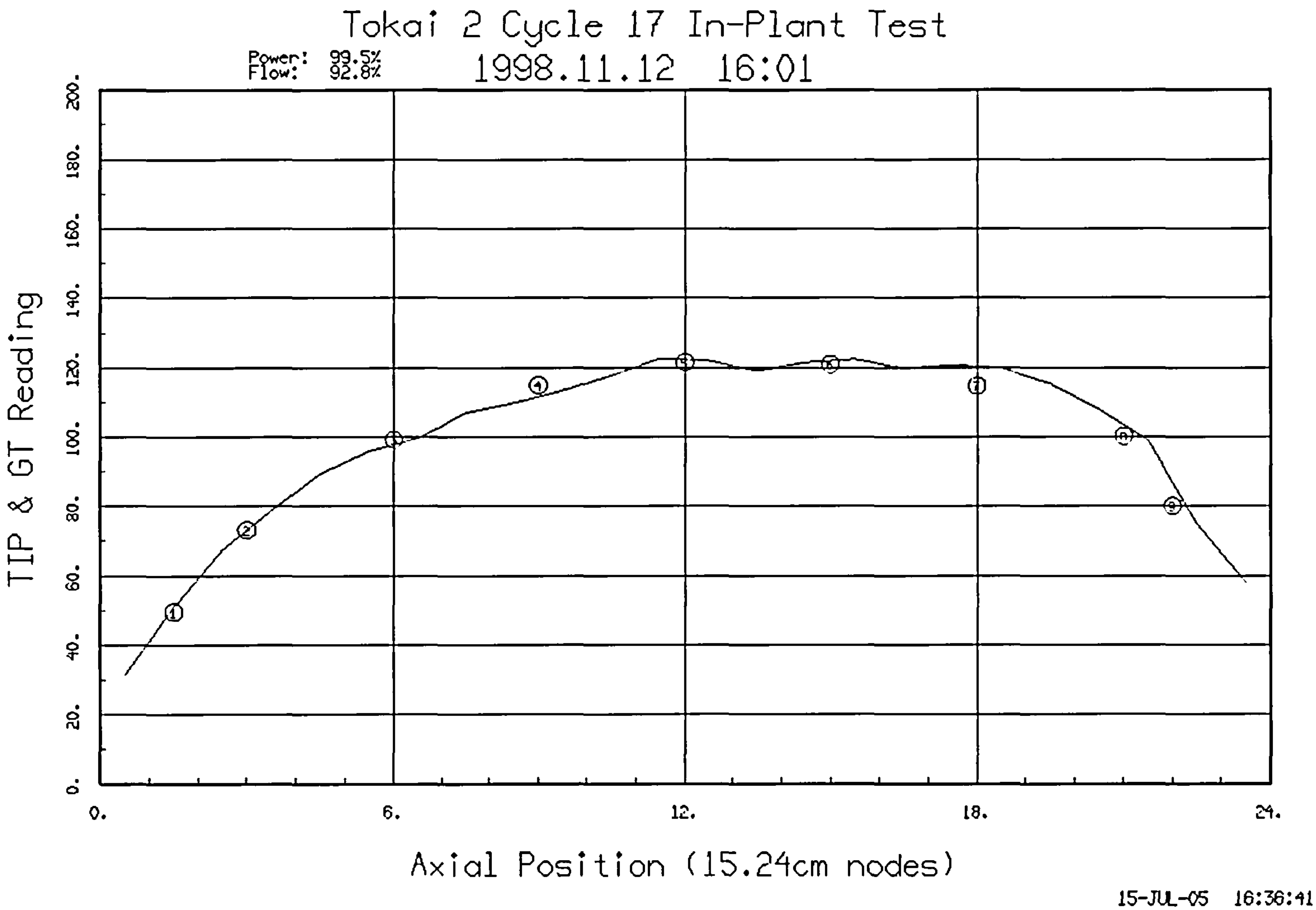


Figure 7-42, Comparison of GT with TIP Readings for RSTK-02

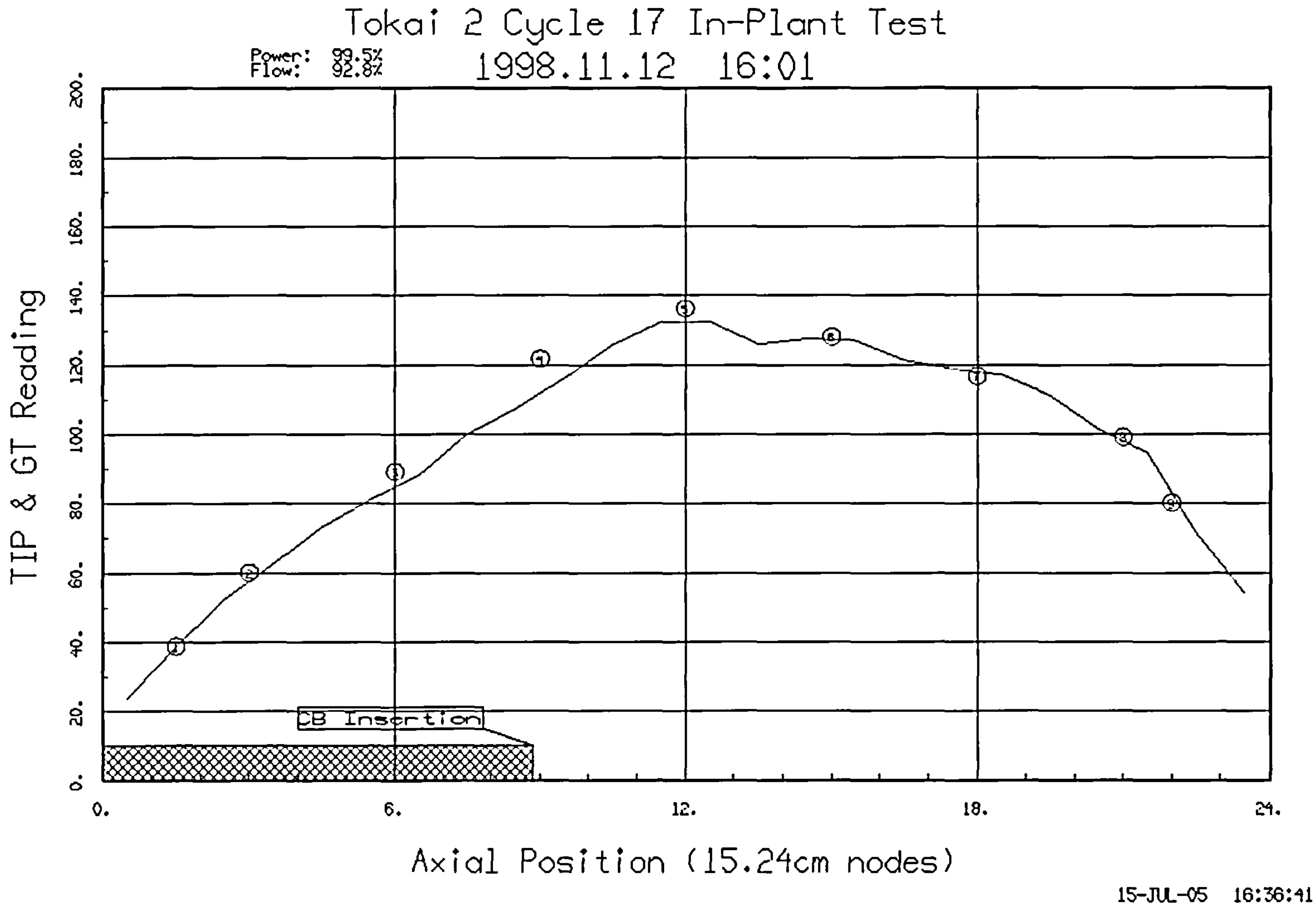


Figure 7-43, Comparison of GT with TIP Readings for RSTK-01

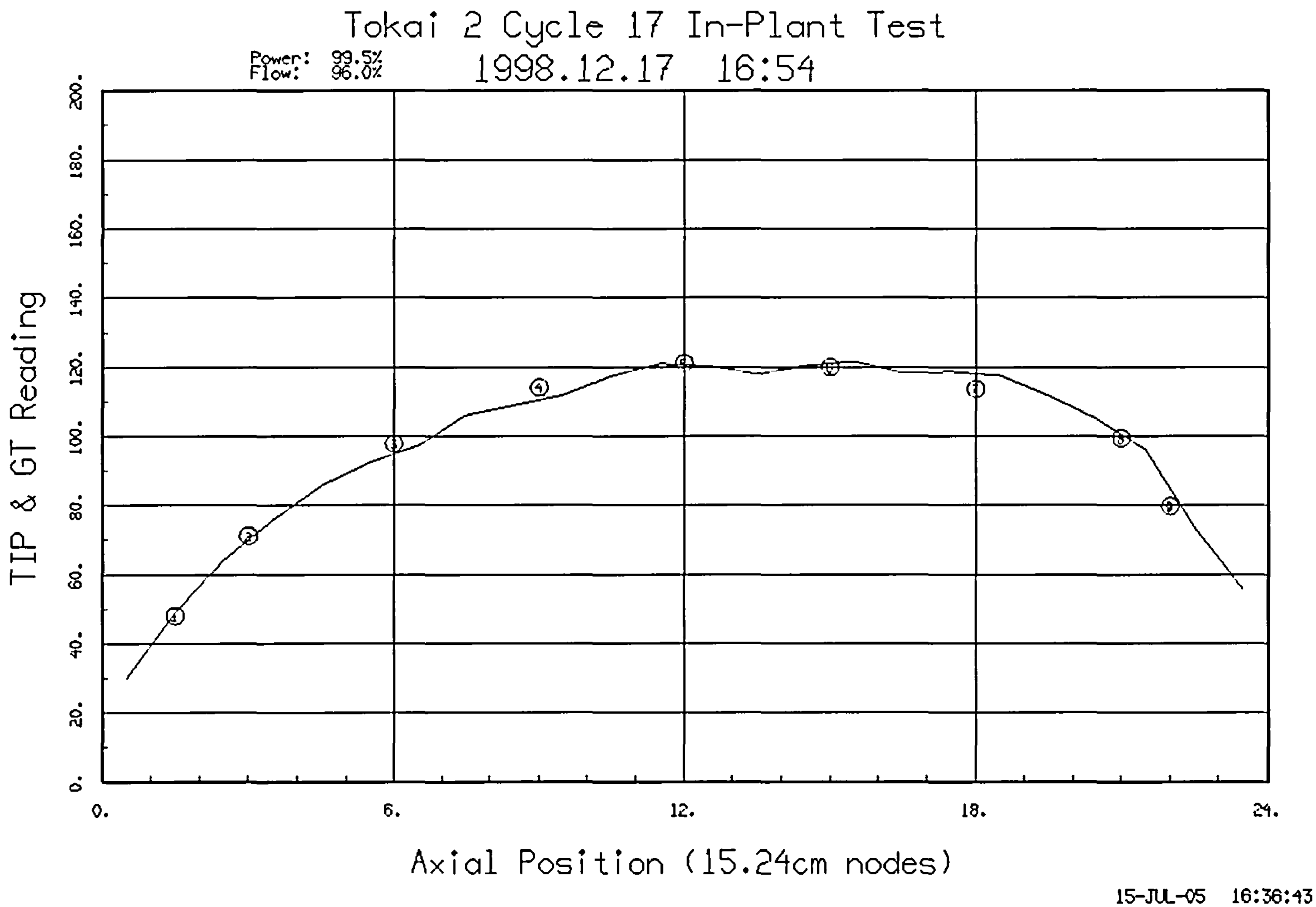


Figure 7-44, Comparison of GT with TIP Readings for RSTK-02

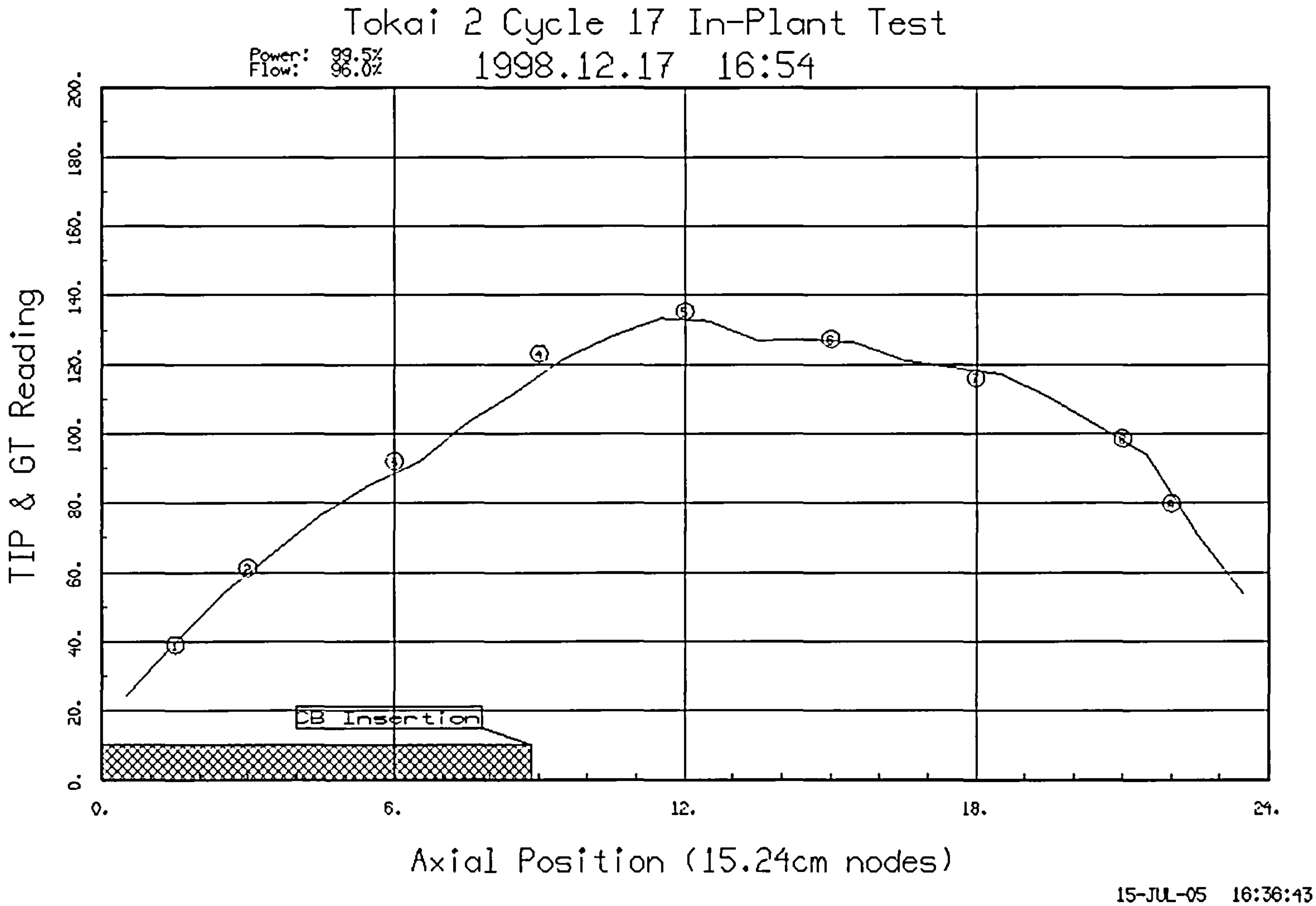


Figure 7-45, Comparison of GT with TIP Readings for RSTK-01

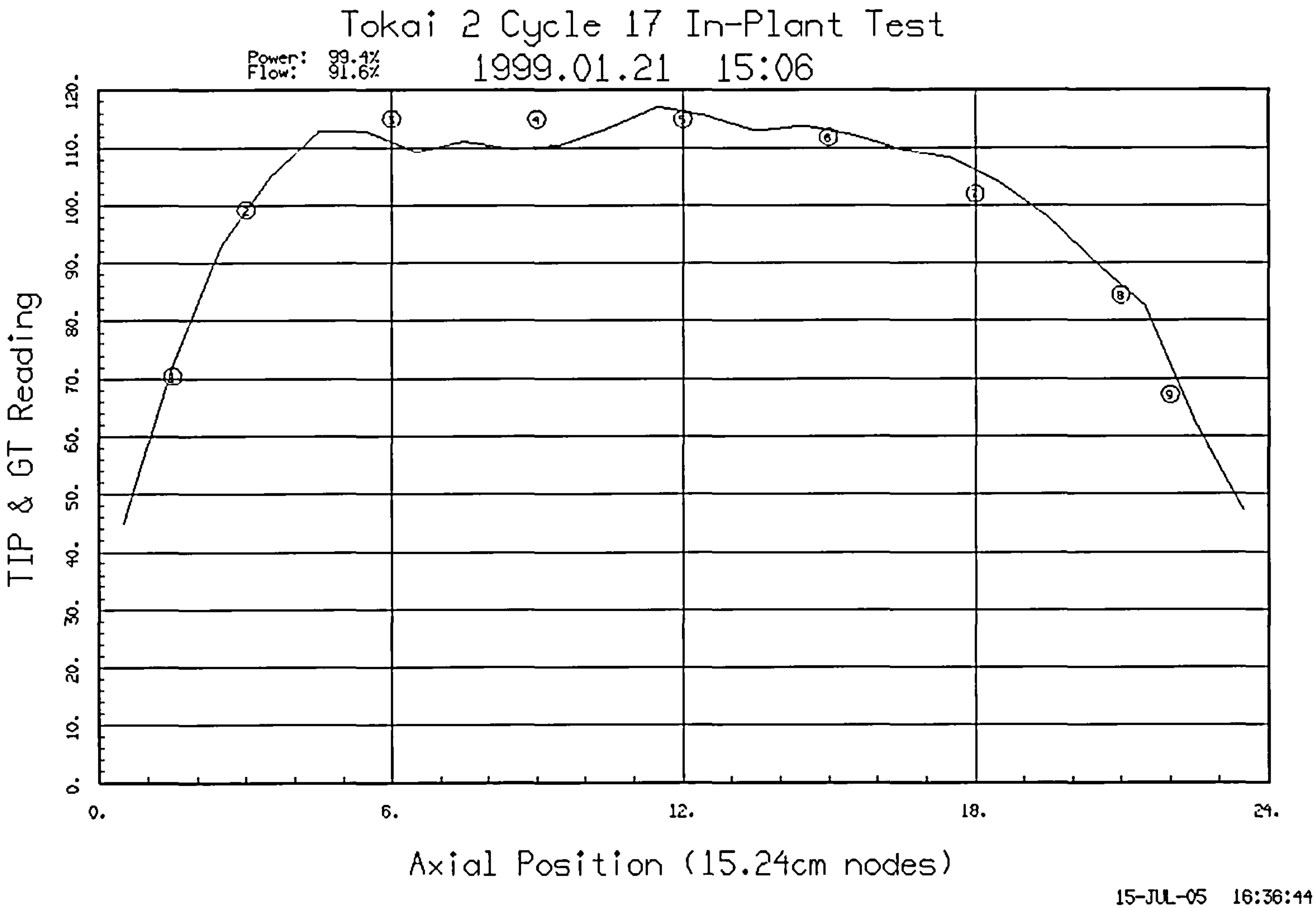


Figure 7-46, Comparison of GT with TIP Readings for RSTK-02

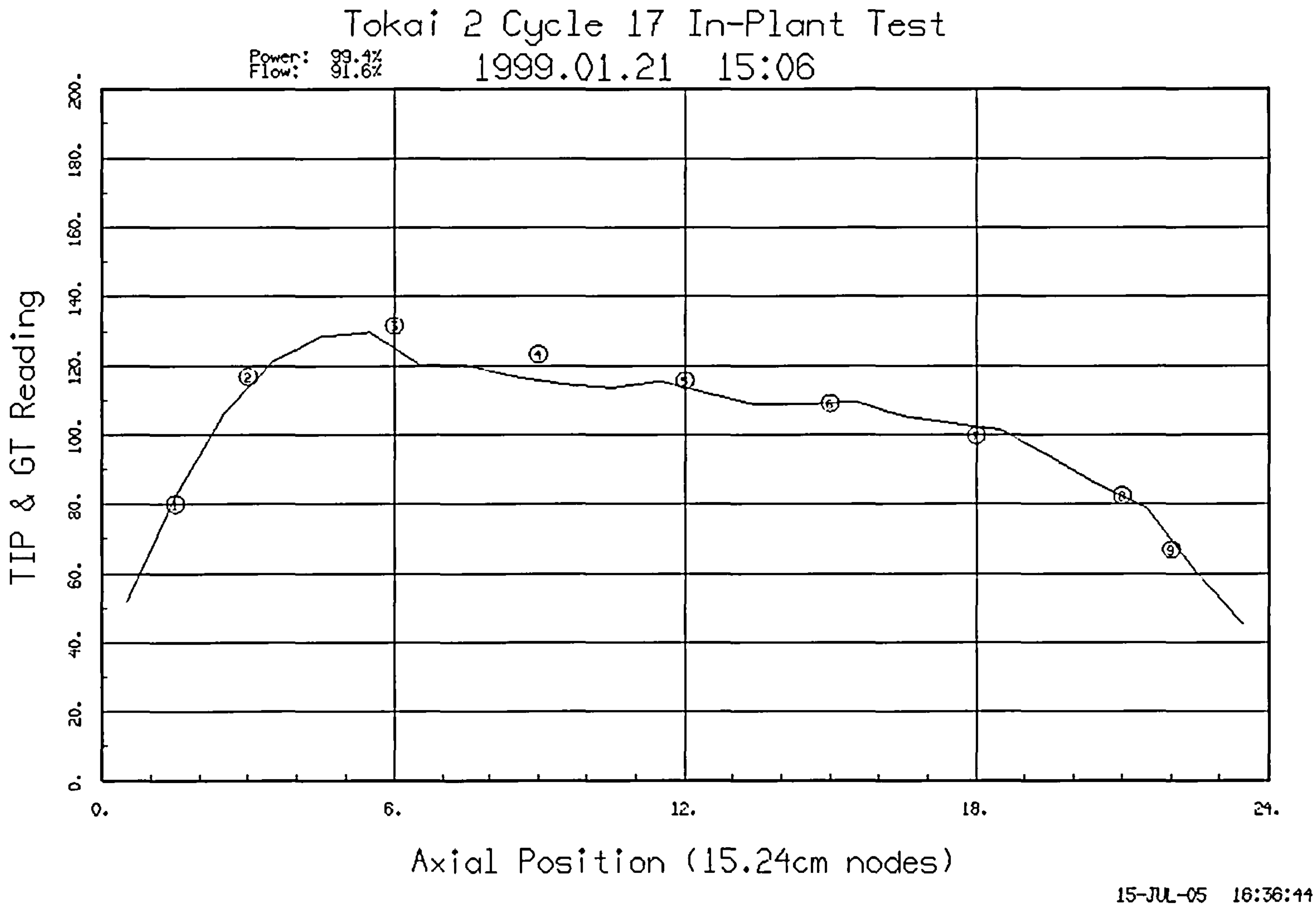


Figure 7-47, Comparison of GT with TIP Readings for RSTK-01

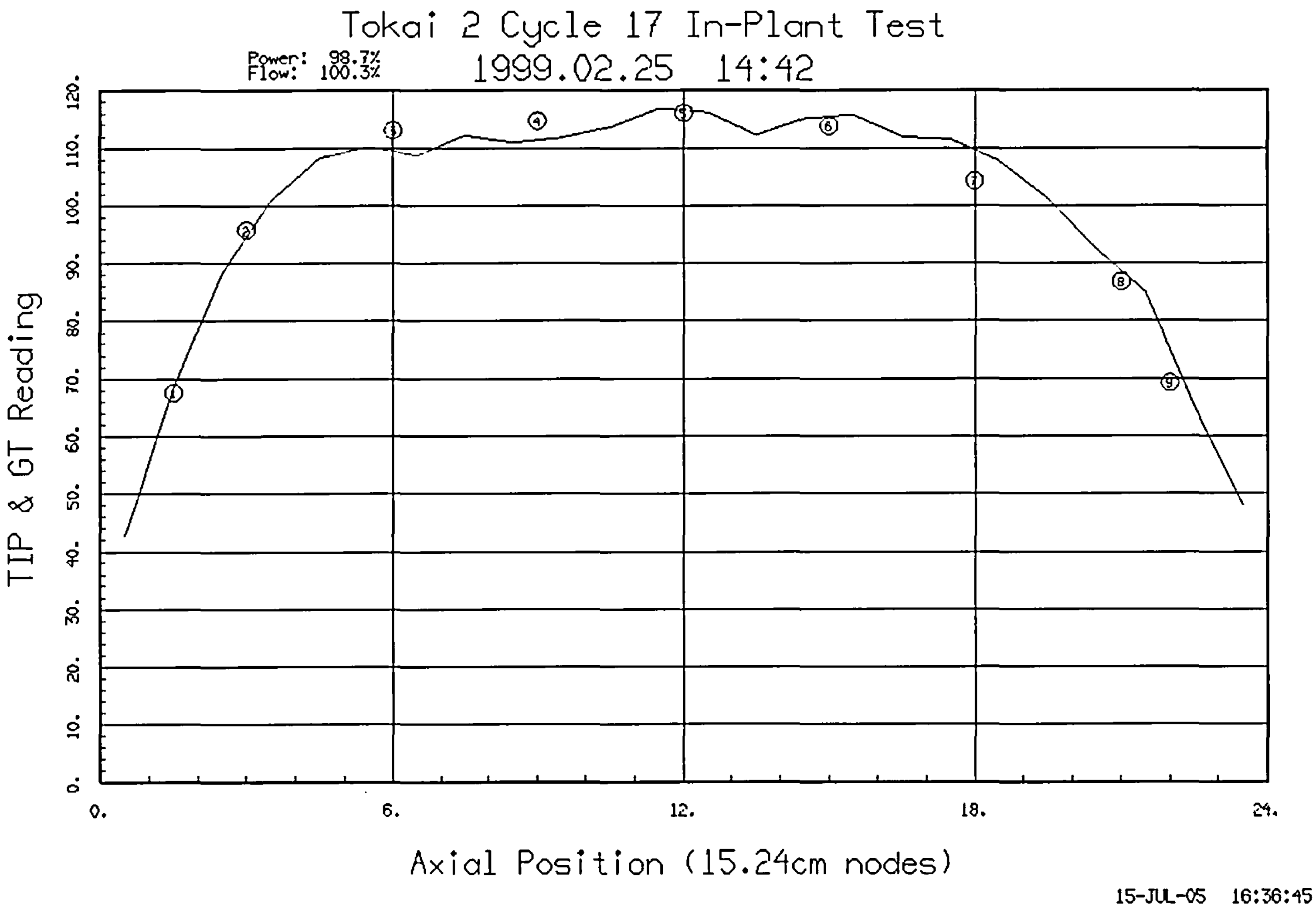


Figure 7-48, Comparison of GT with TIP Readings for RSTK-02

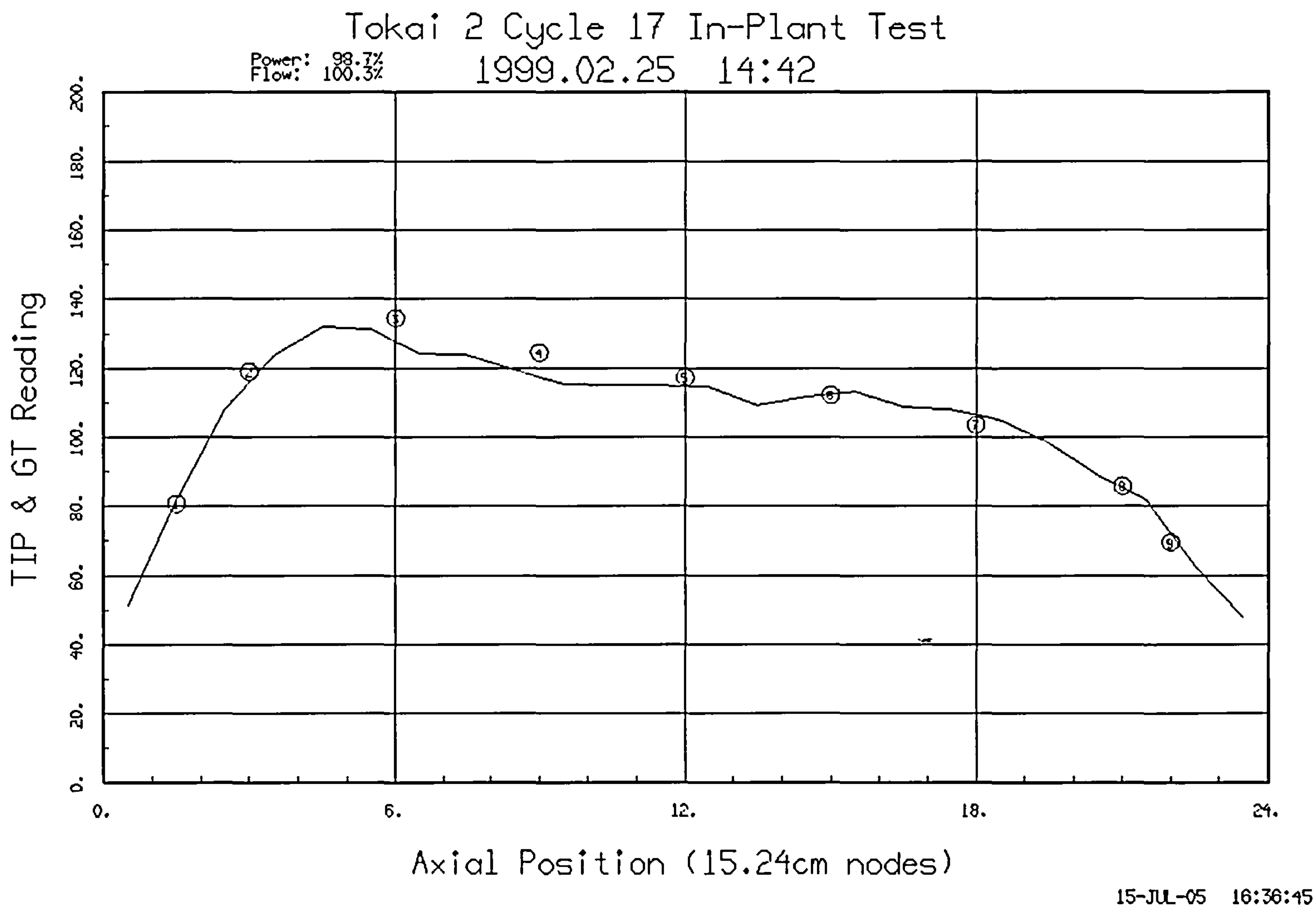


Figure 7-49, Comparison of GT with TIP Readings for RSTK-01

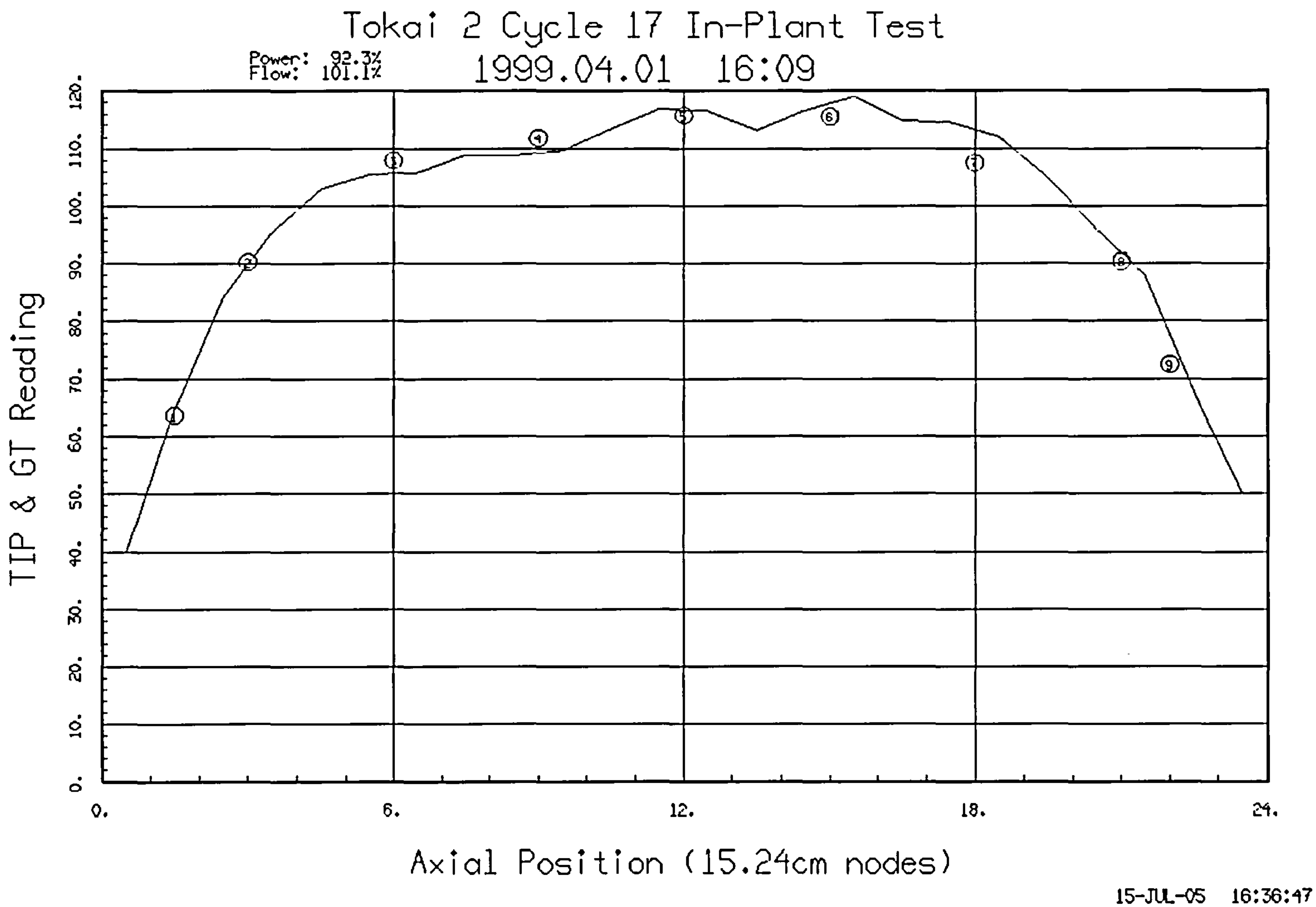
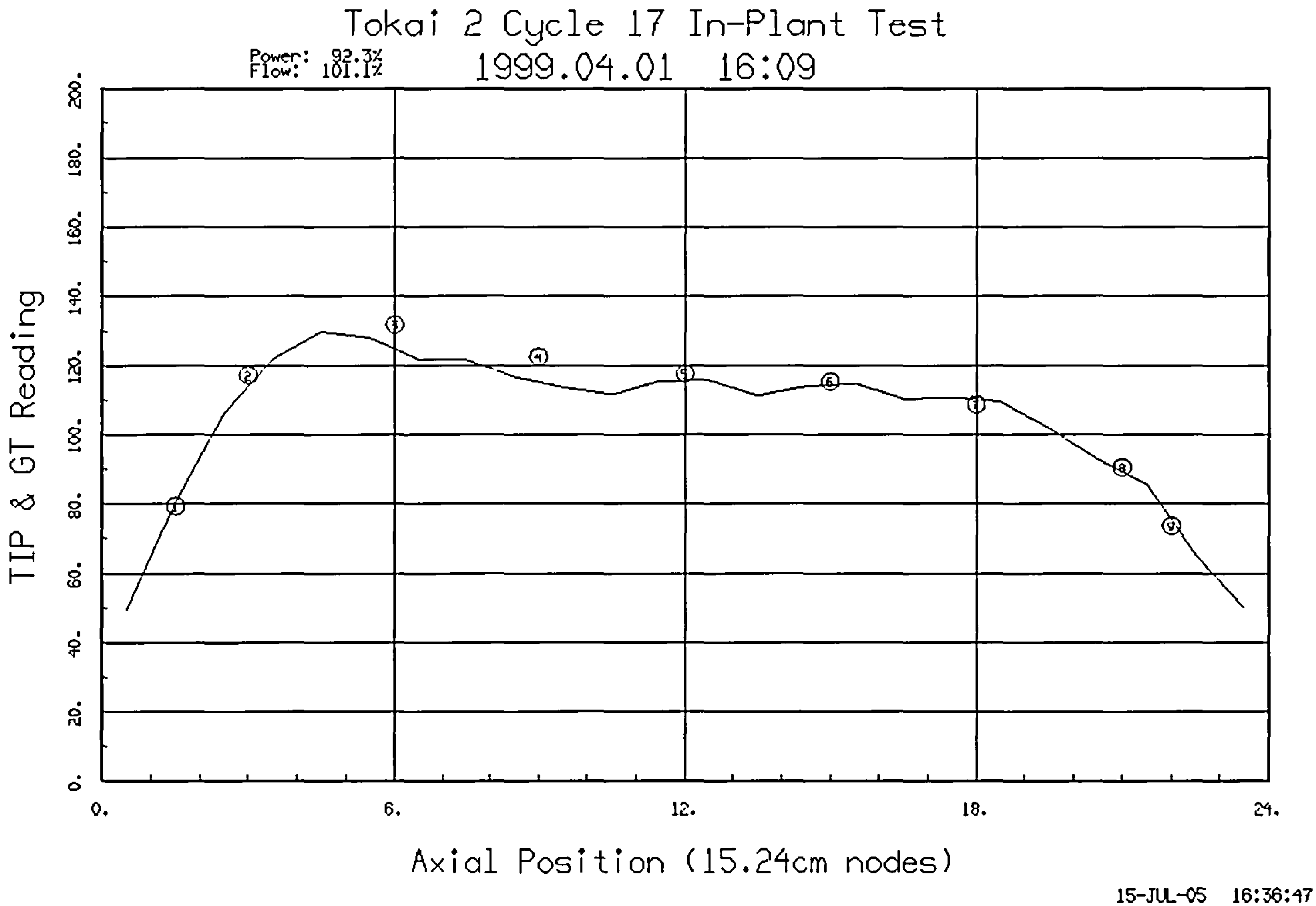


Figure 7-50, Comparison of GT with TIP Readings for RSTK-02

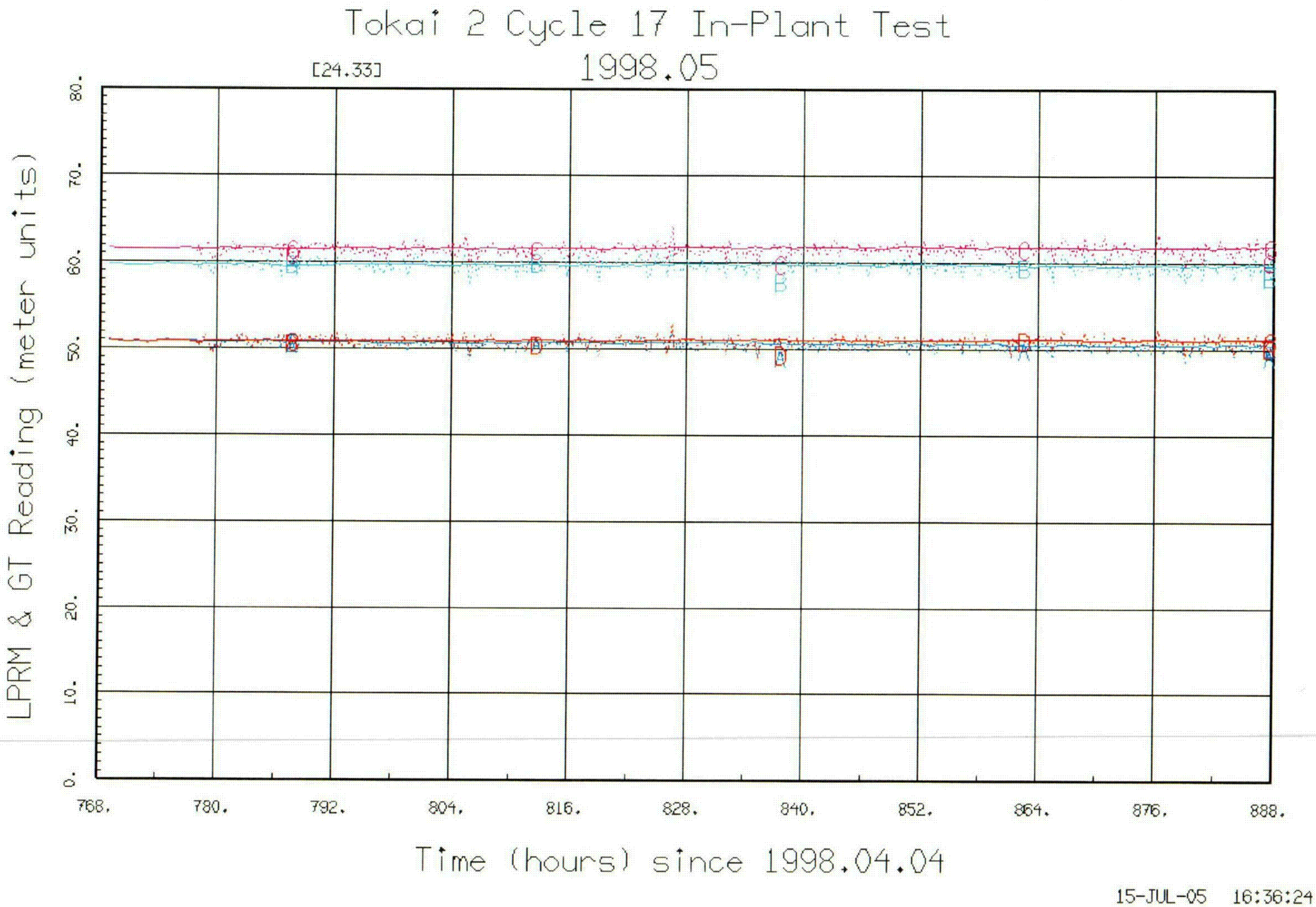


7.2.5.2 Comparison with LPRMs

[[

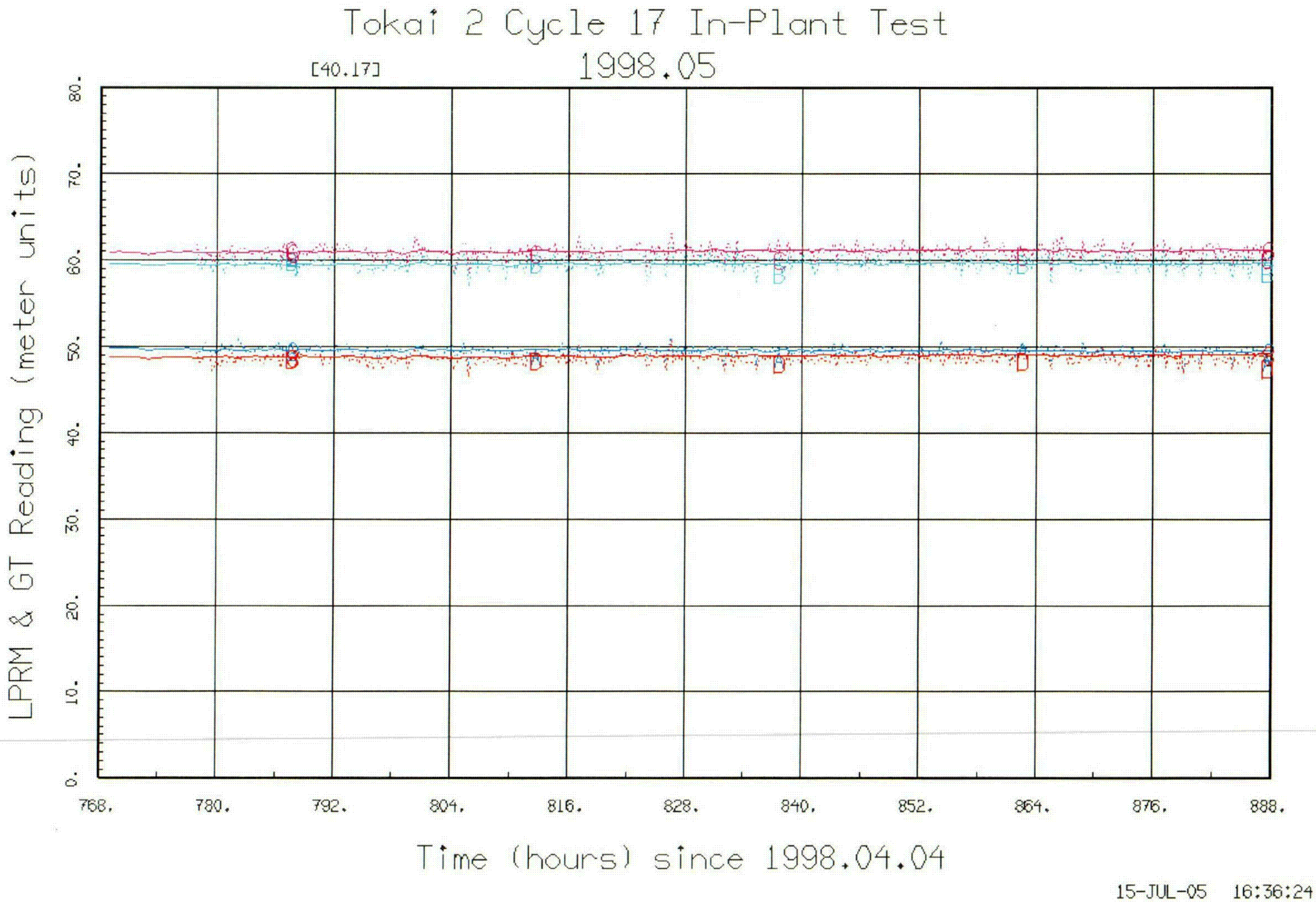
]]

Figure 7-51, Comparison of GT with LPRM Readings for RSTK-01 (steady-state)



C13

Figure 7-52, Comparison of GT with LPRM Readings for RSTK-02 (steady-state)



C14

7.2.6 Response During Transients

[[

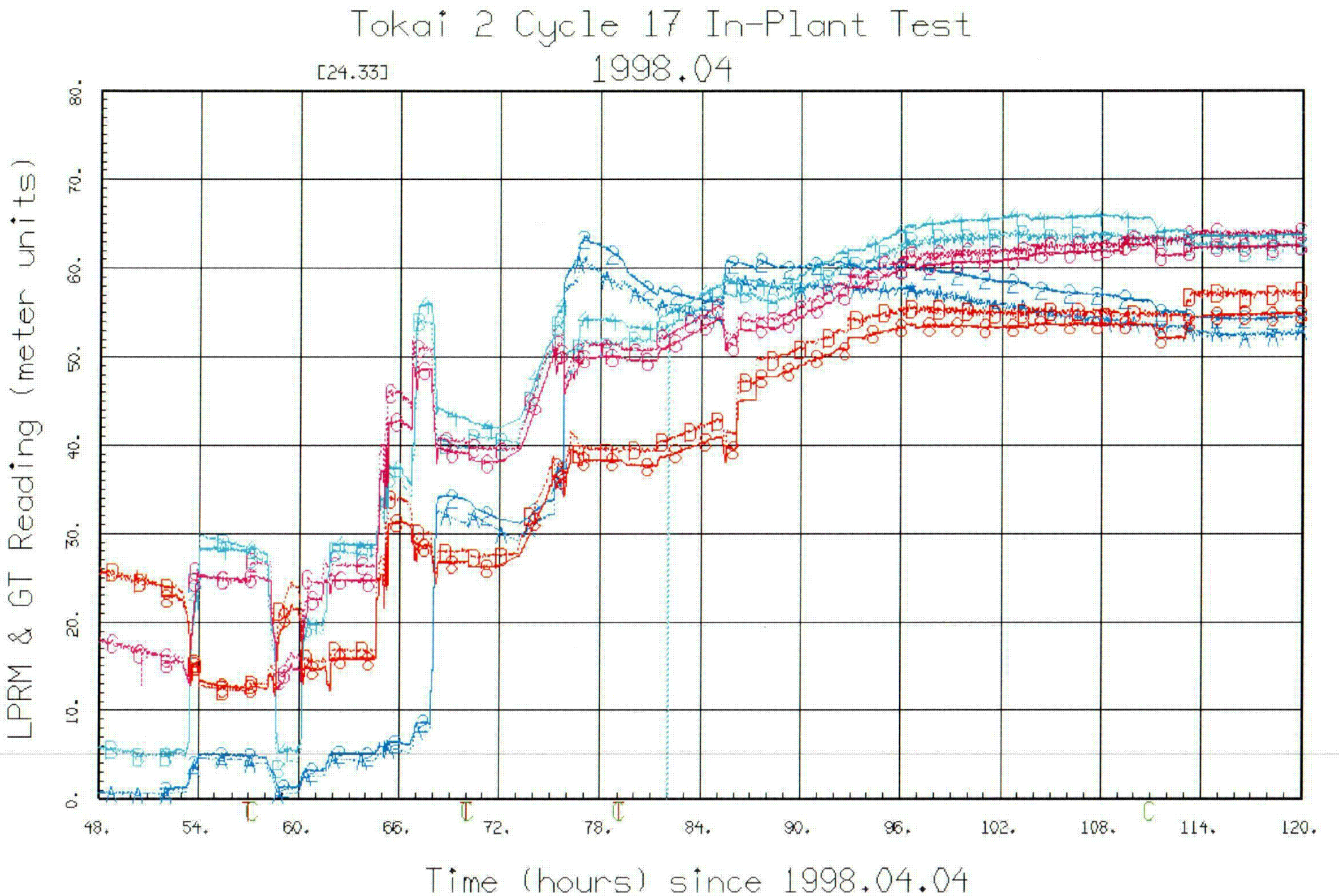
]]

7.2.6.1 Response During Startup

[[

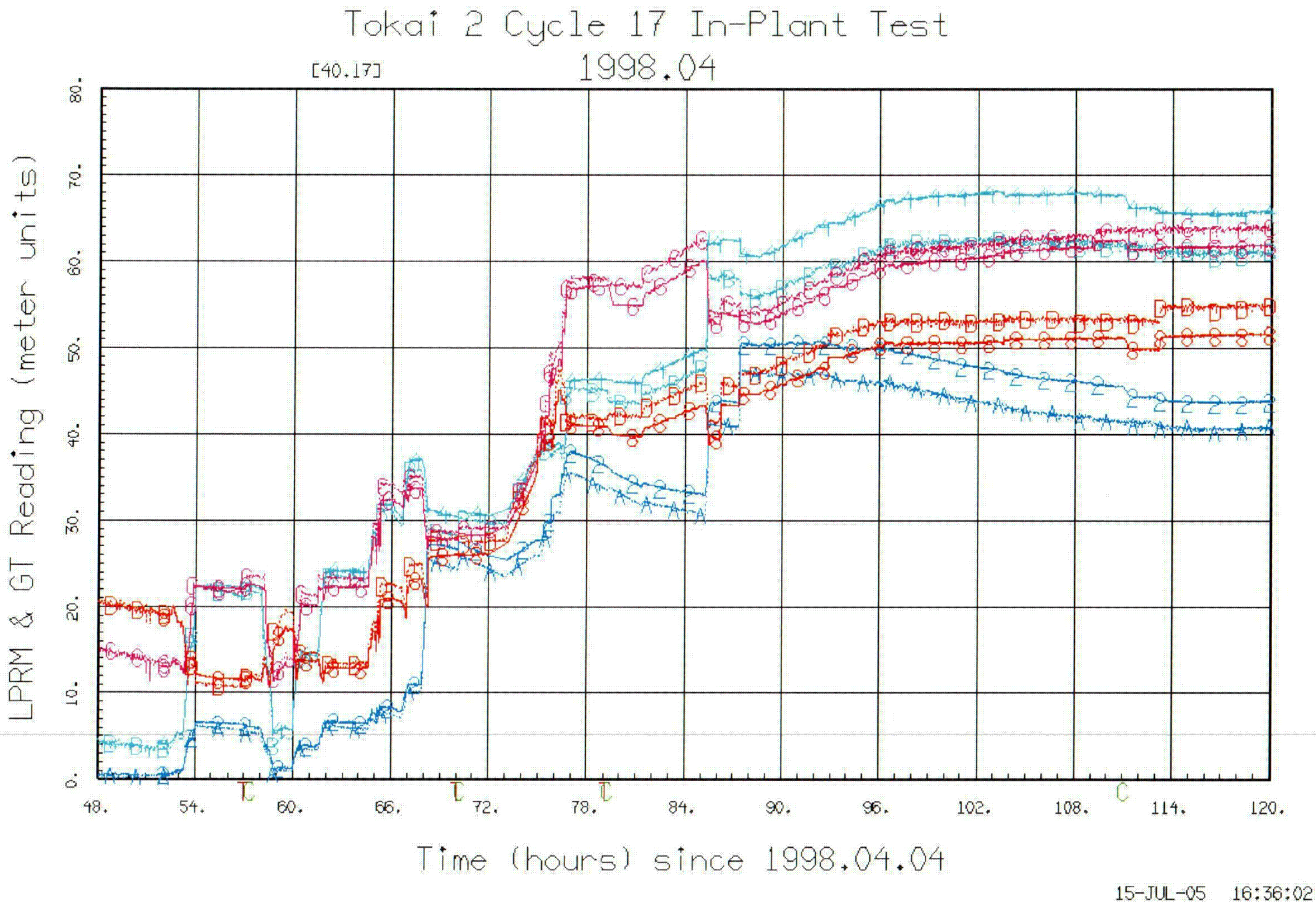
]]

Figure 7-53, Comparison of GT with LPRM Readings for RSTK-01 (startup)



C15

Figure 7-54, Comparison of GT with LPRM Readings for RSTK-02 (startup)



C16

7.2.6.2 Response to Flow Change

[[

]]

Table 7-10, Comparison of Un-Compensated GT with LPRM Readings for RSTK-01 (flow change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	35.1	35.1	0.0	61.2	61.2	0.0	70.0	70.0	0.1	61.7	61.6	0.1
8:30	99.6	99.5	35.1	35.1	0.0	61.1	61.3	-0.2	69.9	69.8	0.1	61.7	61.8	-0.1
9:00	99.3	99.8	35.2	35.0	0.5	61.4	61.2	0.3	70.2	70.0	0.4	62.0	61.8	0.3
9:05	98.8	98.6	35.0	34.9	0.4	61.0	60.8	0.5	69.8	69.4	0.7	61.7	61.4	0.5
9:10	96.9	95.1	34.7	34.4	0.9	60.2	59.4	1.3	68.9	68.0	1.3	61.0	60.3	1.1
9:15	91.6	87.1	33.5	32.8	2.2	57.6	56.1	2.5	65.9	64.2	2.6	58.6	57.5	1.9
9:20	87.2	79.8	32.3	31.5	2.6	54.8	53.0	3.5	62.8	60.9	3.0	56.2	54.7	2.7
9:25	84.3	75.1	31.3	30.5	2.7	52.8	51.1	3.4	60.5	58.6	3.2	54.3	53.1	2.2
9:30	82.1	71.6	30.5	29.9	1.9	51.1	49.6	3.1	58.3	57.1	2.3	52.6	51.7	1.6
9:35	82.2	71.6	30.4	30.3	0.2	51.0	49.7	2.7	58.3	56.7	2.9	52.6	51.7	1.8

Table 7-11, Comparison of Un-Compensated GT with LPRM Readings for RSTK-02 (flow change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	27.4	27.5	-0.3	66.7	67.0	-0.3	71.5	71.7	-0.2	61.7	61.8	-0.2
8:30	99.6	99.5	27.4	27.6	-0.5	67.0	67.2	-0.3	71.6	71.9	-0.4	61.6	61.8	-0.3
9:00	99.3	99.8	27.5	27.4	0.5	67.3	66.7	0.9	71.9	71.6	0.5	61.9	61.7	0.4
9:05	98.8	98.6	27.3	27.4	-0.3	66.8	66.5	0.5	71.3	71.0	0.5	61.4	61.3	0.3
9:10	96.9	95.1	27.2	26.9	1.0	66.0	65.0	1.5	70.5	69.6	1.3	60.8	60.1	1.1
9:15	91.6	87.1	26.2	25.7	2.0	63.0	61.3	2.7	67.3	65.6	2.6	58.3	57.0	2.2
9:20	87.2	79.8	25.2	24.7	2.1	60.1	58.2	3.1	64.1	62.2	3.0	55.7	54.4	2.5
9:25	84.3	75.1	24.5	23.9	2.4	58.0	56.3	3.0	61.7	60.0	2.9	53.8	52.6	2.4

9:30	82.1	71.6	23.7	23.5	1.1	55.9	54.6	2.5	59.5	58.2	2.2	51.9	51.2	1.4
9:35	82.2	71.6	23.7	23.5	0.9	55.9	54.8	2.1	59.5	58.5	1.6	52.0	51.3	1.3

Table 7-12, Comparison of Delayed Gamma Compensated GT with LPRM Readings for RSTK-01 (flow change)

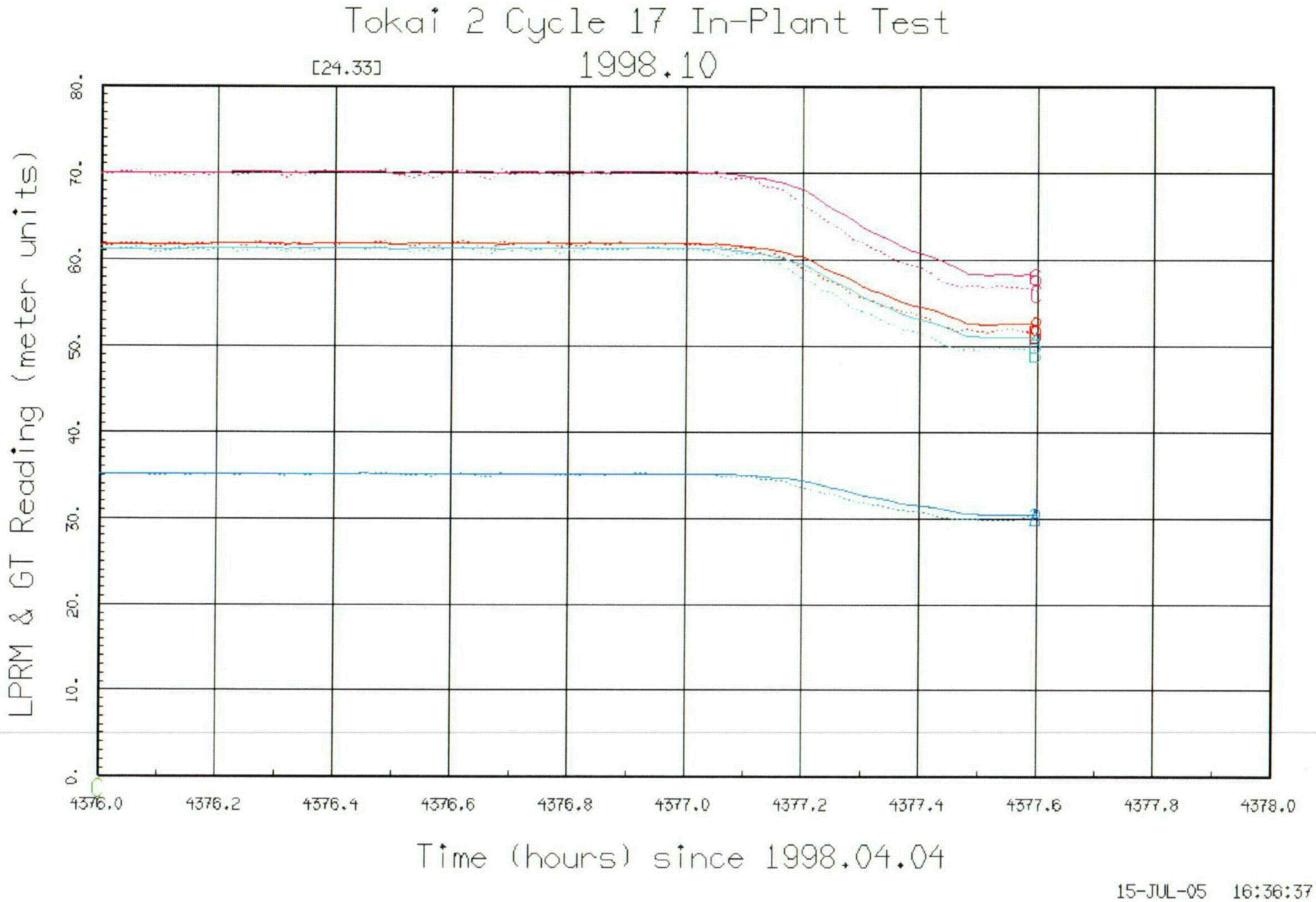
Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	35.1	35.1	0.0	61.2	61.2	0.1	70.0	70.0	0.1	61.7	61.6	0.1
8:30	99.6	99.5	35.0	35.1	-0.3	61.0	61.3	-0.4	69.8	69.8	-0.1	61.6	61.8	-0.3
9:00	99.3	99.8	35.2	35.0	0.5	61.5	61.2	0.4	70.3	70.0	0.4	62.0	61.8	0.4
9:05	98.8	98.6	35.0	34.9	0.2	60.9	60.8	0.3	69.7	69.4	0.5	61.6	61.4	0.3
9:10	96.9	95.1	34.6	34.4	0.6	59.9	59.4	0.8	68.6	68.0	0.8	60.7	60.3	0.7
9:15	91.6	87.1	33.1	32.8	0.8	56.5	56.1	0.7	64.7	64.2	0.9	57.7	57.5	0.3
9:20	87.2	79.8	31.7	31.5	0.8	53.5	53.0	1.1	61.3	60.9	0.6	55.0	54.7	0.6
9:25	84.3	75.1	30.7	30.5	0.5	51.4	51.1	0.5	58.8	58.6	0.4	53.0	53.1	-0.3
9:30	82.1	71.6	29.8	29.9	-0.3	49.7	49.6	0.2	56.7	57.1	-0.6	51.3	51.7	-0.9
9:35	82.2	71.6	29.8	30.3	-1.8	49.9	49.7	0.3	57.0	56.7	0.5	51.5	51.7	-0.3

Table 7-13, Comparison of Delayed Gamma Compensated GT with LPRM Readings for RSTK-02 (flow change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	27.4	27.5	-0.1	66.8	67.0	-0.3	71.6	71.7	-0.2	61.7	61.8	-0.1
8:30	99.6	99.5	27.4	27.6	-0.6	66.8	67.2	-0.6	71.4	71.9	-0.7	61.5	61.8	-0.5
9:00	99.3	99.8	27.6	27.4	0.8	67.4	66.7	1.0	72.0	71.6	0.6	61.9	61.7	0.4
9:05	98.8	98.6	27.3	27.4	-0.5	66.6	66.5	0.2	71.2	71.0	0.3	61.3	61.3	0.0
9:10	96.9	95.1	27.1	26.9	0.7	65.7	65.0	1.0	70.2	69.6	0.8	60.5	60.1	0.7
9:15	91.6	87.1	25.8	25.7	0.7	61.8	61.3	0.8	66.2	65.6	0.8	57.3	57.0	0.6
9:20	87.2	79.8	24.8	24.7	0.3	58.6	58.2	0.7	62.5	62.2	0.5	54.5	54.4	0.2
9:25	84.3	75.1	24.0	23.9	0.3	56.4	56.3	0.3	60.1	60.0	0.1	52.4	52.6	-0.3

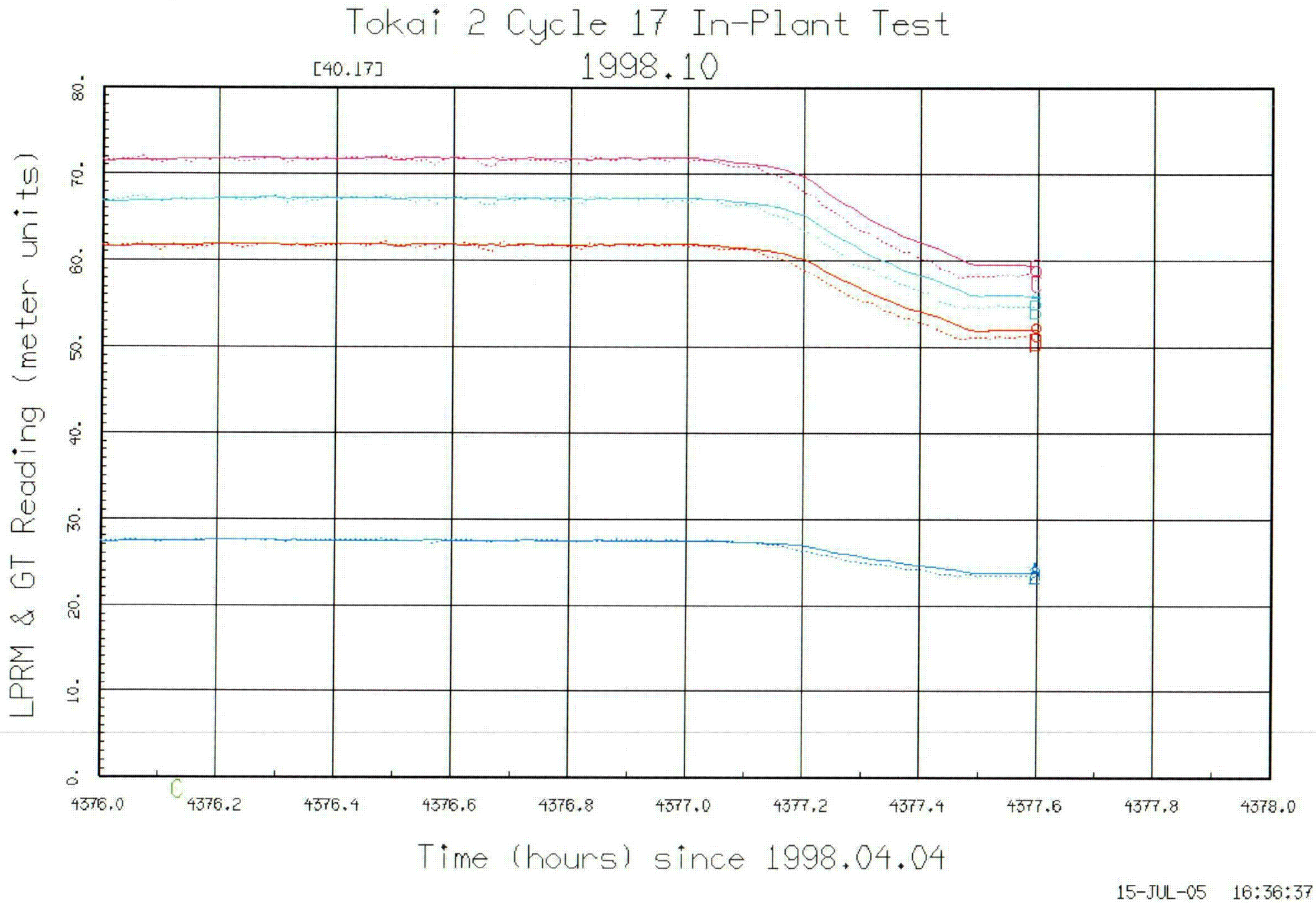
9:30	82.1	71.6	23.2	23.5	-1.4	54.3	54.6	-0.4	57.7	58.2	-0.8	50.5	51.2	-1.4
9:35	82.2	71.6	23.2	23.5	-1.0	54.6	54.8	-0.4	58.0	58.5	-0.9	50.8	51.3	-1.0

Figure 7-55, Un-Compensated GT vs. LPRM Readings for RSTK-01 (flow change)



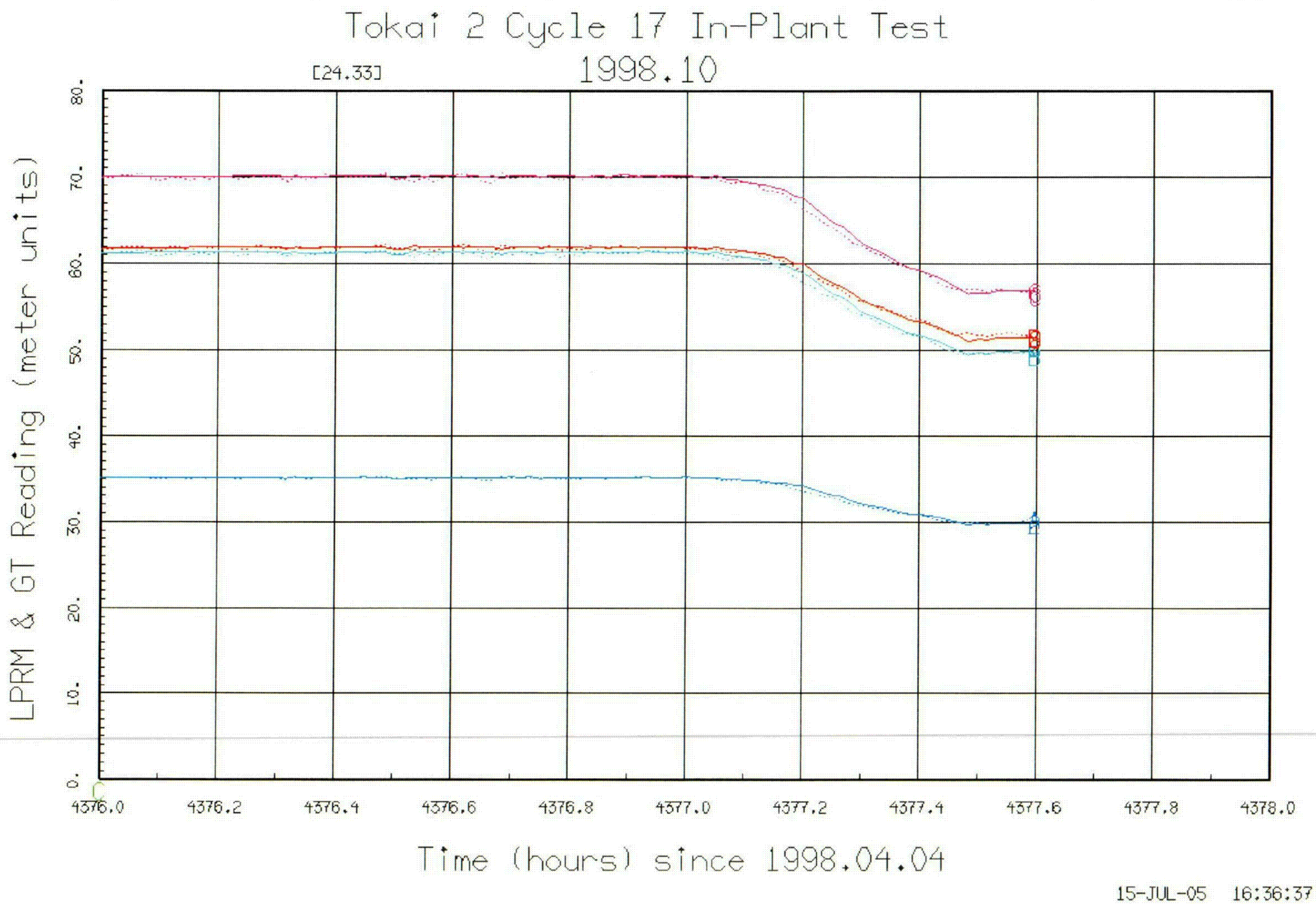
C17

Figure 7-56, Un-Compensated GT vs. LPRM Readings for RSTK-02 (flow change)



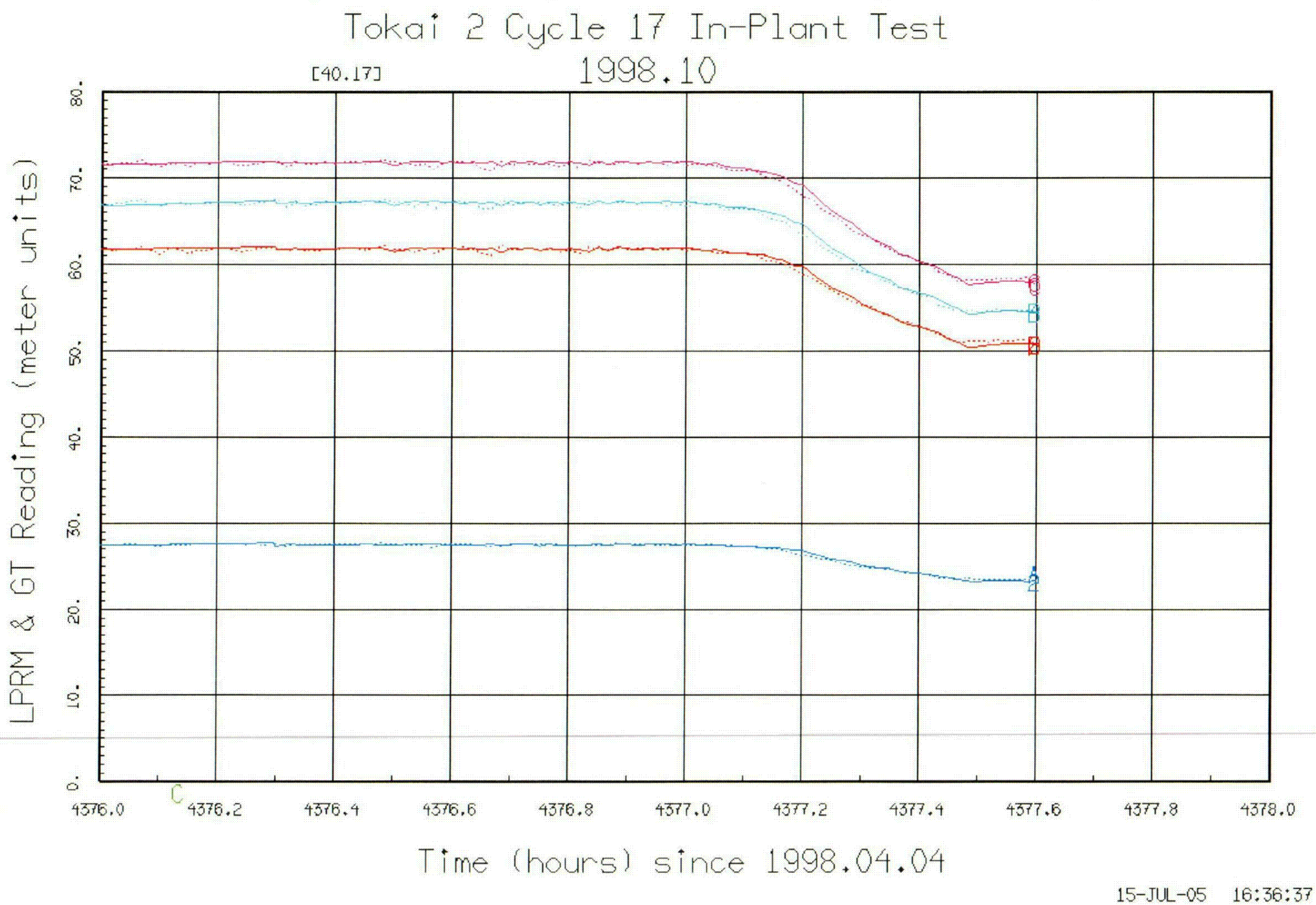
C18

Figure 7-57, Delayed Gamma Comp. GT vs. LPRM Readings for RSTK-01 (flow change)



C19

Figure 7-58, Delayed Gamma Comp. GT vs. LPRM Readings for RSTK-02 (flow change)



C20

7.2.6.3 Response to Control Rod Movement

[[

]]

Table 7-14, Comparison of Un-Compensated GT with LPRM Readings for RSTK-01 (control blade pattern change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	35.1	35.1	0.0	61.2	61.2	0.0	70.0	70.0	0.1	61.7	61.6	0.1
8:30	99.6	99.5	35.1	35.1	0.0	61.1	61.3	-0.2	69.9	69.8	0.1	61.7	61.8	-0.1
9:00	99.3	99.8	35.2	35.0	0.5	61.4	61.2	0.3	70.2	70.0	0.4	62.0	61.8	0.3
9:05	98.8	98.6	35.0	34.9	0.4	61.0	60.8	0.5	69.8	69.4	0.7	61.7	61.4	0.5
9:10	96.9	95.1	34.7	34.4	0.9	60.2	59.4	1.3	68.9	68.0	1.3	61.0	60.3	1.1
9:15	91.6	87.1	33.5	32.8	2.2	57.6	56.1	2.5	65.9	64.2	2.6	58.6	57.5	1.9
9:20	87.2	79.8	32.3	31.5	2.6	54.8	53.0	3.5	62.8	60.9	3.0	56.2	54.7	2.7
9:25	84.3	75.1	31.3	30.5	2.7	52.8	51.1	3.4	60.5	58.6	3.2	54.3	53.1	2.2
9:30	82.1	71.6	30.5	29.9	1.9	51.1	49.6	3.1	58.3	57.1	2.3	52.6	51.7	1.6
9:35	82.2	71.6	30.4	30.3	0.2	51.0	49.7	2.7	58.3	56.7	2.9	52.6	51.7	1.8
9:40	81.7	71.5	31.5	31.2	0.9	50.4	48.9	3.1	57.0	55.4	3.0	51.7	51.0	1.5
9:45	83.7	71.4	31.8	31.5	1.1	51.0	49.7	2.6	58.6	57.4	2.1	52.7	52.3	0.9
9:50	83.4	71.5	31.8	31.4	1.2	50.8	49.7	2.2	58.5	57.3	2.1	52.7	52.1	1.0
9:55	85.8	71.0	32.3	32.1	0.8	52.3	51.4	1.9	60.5	59.6	1.5	52.4	51.6	1.5
10:00	86.3	71.1	33.2	34.2	-3.0	53.8	53.2	1.1	59.9	57.6	3.9	50.9	49.4	3.2
10:05	85.7	71.1	36.2	37.3	-3.0	53.5	51.7	3.4	57.7	55.7	3.4	49.3	48.0	2.7
10:10	85.7	71.3	37.4	37.3	0.4	52.5	51.2	2.4	56.8	55.8	1.7	48.8	48.3	1.1
10:15	85.5	71.3	35.8	35.3	1.3	52.5	51.2	2.5	58.2	57.5	1.2	49.9	49.6	0.5
10:20	85.3	71.4	35.1	35.1	0.0	52.3	51.3	2.1	58.8	57.8	1.8	50.4	49.9	1.0
10:25	88.5	76.0	36.1	36.2	-0.3	54.1	53.3	1.5	60.7	59.9	1.4	52.1	51.6	0.9
10:30	91.2	80.3	36.9	37.0	-0.3	55.7	54.7	1.8	62.7	61.9	1.2	53.5	53.0	1.0
10:35	90.8	80.3	36.9	37.0	-0.1	55.6	54.8	1.4	62.6	61.7	1.4	53.4	52.7	1.3

10:40	91.0	80.4	36.9	37.0	-0.3	55.6	54.7	1.6	62.5	61.7	1.3	53.3	52.8	0.9
10:45	90.8	80.3	37.0	36.9	0.0	55.6	54.6	1.8	62.5	61.6	1.5	53.3	52.7	1.2
10:50	91.5	81.2	37.1	37.3	-0.4	55.8	55.1	1.4	62.8	62.0	1.3	53.5	53.4	0.3
11:00	91.3	81.3	37.3	37.3	-0.1	55.9	54.8	2.1	62.9	62.0	1.4	53.5	53.1	0.7
11:30	91.6	82.1	37.6	37.6	0.1	56.2	55.2	1.8	63.1	62.4	1.2	53.6	53.3	0.7
12:00	92.3	82.9	37.8	37.8	0.0	56.3	55.4	1.7	63.3	62.5	1.3	53.7	53.3	0.7

Table 7-15, Comparison of Un-Compensated GT with LPRM Readings for RSTK-02 (control blade pattern change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	27.4	27.5	-0.3	66.7	67.0	-0.3	71.5	71.7	-0.2	61.7	61.8	-0.2
8:30	99.6	99.5	27.4	27.6	-0.5	67.0	67.2	-0.3	71.6	71.9	-0.4	61.6	61.8	-0.3
9:00	99.3	99.8	27.5	27.4	0.5	67.3	66.7	0.9	71.9	71.6	0.5	61.9	61.7	0.4
9:05	98.8	98.6	27.3	27.4	-0.3	66.8	66.5	0.5	71.3	71.0	0.5	61.4	61.3	0.3
9:10	96.9	95.1	27.2	26.9	1.0	66.0	65.0	1.5	70.5	69.6	1.3	60.8	60.1	1.1
9:15	91.6	87.1	26.2	25.7	2.0	63.0	61.3	2.7	67.3	65.6	2.6	58.3	57.0	2.2
9:20	87.2	79.8	25.2	24.7	2.1	60.1	58.2	3.1	64.1	62.2	3.0	55.7	54.4	2.5
9:25	84.3	75.1	24.5	23.9	2.4	58.0	56.3	3.0	61.7	60.0	2.9	53.8	52.6	2.4
9:30	82.1	71.6	23.7	23.5	1.1	55.9	54.6	2.5	59.5	58.2	2.2	51.9	51.2	1.4
9:35	82.2	71.6	23.7	23.5	0.9	55.9	54.8	2.1	59.5	58.5	1.6	52.0	51.3	1.3
9:40	81.7	71.5	26.2	26.4	-0.7	56.0	54.2	3.2	57.6	55.8	3.1	50.9	49.8	2.1
9:45	83.7	71.4	26.6	26.6	-0.1	56.3	55.0	2.4	58.6	57.6	1.8	51.7	51.2	1.0
9:50	83.4	71.5	26.5	26.4	0.4	56.1	54.6	2.7	58.5	57.5	1.7	51.6	51.0	1.1
9:55	85.8	71.0	27.0	27.2	-0.8	57.1	56.5	1.2	60.0	59.5	0.8	51.8	50.6	2.4
10:00	86.3	71.1	27.6	27.7	-0.5	59.0	57.9	1.9	60.0	58.9	1.9	50.2	49.0	2.5
10:05	85.7	71.1	28.9	29.9	-3.4	59.2	57.2	3.5	58.5	56.6	3.5	48.9	47.6	2.9
10:10	85.7	71.3	30.6	30.1	1.5	57.9	56.4	2.7	57.1	56.7	0.9	48.1	47.8	0.7
10:15	85.5	71.3	27.3	26.8	2.1	57.4	54.9	4.6	59.8	59.3	0.8	49.9	49.5	0.7
10:20	85.3	71.4	26.3	26.0	1.0	52.2	51.0	2.3	61.4	61.0	0.8	50.9	50.4	1.1
10:25	88.5	76.0	26.8	26.8	0.1	53.6	53.1	0.9	63.4	63.6	-0.3	52.7	52.8	-0.3
10:30	91.2	80.3	27.5	27.5	-0.1	55.3	54.7	1.2	65.7	65.4	0.4	54.5	54.1	0.7
10:35	90.8	80.3	27.5	27.3	0.9	55.2	54.5	1.2	65.6	65.4	0.3	54.3	54.0	0.6

10:40	91.0	80.4	27.5	27.4	0.5	55.2	54.6	1.1	65.7	65.5	0.2	54.3	54.0	0.7
10:45	90.8	80.3	27.6	27.4	0.6	55.2	54.5	1.2	65.6	65.4	0.4	54.3	53.9	0.8
10:50	91.5	81.2	27.6	27.6	0.1	55.3	54.9	0.9	66.0	65.9	0.2	54.5	54.2	0.6
11:00	91.3	81.3	27.6	27.6	0.1	55.3	54.6	1.4	66.0	65.7	0.5	54.5	54.2	0.4
11:30	91.6	82.1	27.7	27.7	0.0	55.5	55.2	0.5	66.4	66.3	0.1	54.7	54.5	0.2
12:00	92.3	82.9	27.9	27.9	-0.1	55.6	55.1	0.7	66.6	66.5	0.2	54.7	54.6	0.3

Table 7-16, Comparison of Delayed Gamma Compensated GT with LPRM Readings for RSTK-01 (control blade pattern change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	35.1	35.1	0.0	61.2	61.2	0.1	70.0	70.0	0.1	61.7	61.6	0.1
8:30	99.6	99.5	35.0	35.1	-0.3	61.0	61.3	-0.4	69.8	69.8	-0.1	61.6	61.8	-0.3
9:00	99.3	99.8	35.2	35.0	0.5	61.5	61.2	0.4	70.3	70.0	0.4	62.0	61.8	0.4
9:05	98.8	98.6	35.0	34.9	0.2	60.9	60.8	0.3	69.7	69.4	0.5	61.6	61.4	0.3
9:10	96.9	95.1	34.6	34.4	0.6	59.9	59.4	0.8	68.6	68.0	0.8	60.7	60.3	0.7
9:15	91.6	87.1	33.1	32.8	0.8	56.5	56.1	0.7	64.7	64.2	0.9	57.7	57.5	0.3
9:20	87.2	79.8	31.7	31.5	0.8	53.5	53.0	1.1	61.3	60.9	0.6	55.0	54.7	0.6
9:25	84.3	75.1	30.7	30.5	0.5	51.4	51.1	0.5	58.8	58.6	0.4	53.0	53.1	-0.3
9:30	82.1	71.6	29.8	29.9	-0.3	49.7	49.6	0.2	56.7	57.1	-0.6	51.3	51.7	-0.9
9:35	82.2	71.6	29.8	30.3	-1.8	49.9	49.7	0.3	57.0	56.7	0.5	51.5	51.7	-0.3
9:40	81.7	71.5	31.3	31.2	0.3	49.2	48.9	0.7	55.6	55.4	0.3	50.6	51.0	-0.7
9:45	83.7	71.4	31.6	31.5	0.5	50.1	49.7	0.9	57.7	57.4	0.6	52.1	52.3	-0.4
9:50	83.4	71.5	31.5	31.4	0.6	49.9	49.7	0.5	57.6	57.3	0.5	51.9	52.1	-0.4
9:55	85.8	71.0	32.3	32.1	0.6	52.0	51.4	1.3	60.2	59.6	0.9	51.5	51.6	-0.2
10:00	86.3	71.1	33.3	34.2	-2.6	53.7	53.2	0.9	59.3	57.6	2.8	49.9	49.4	1.2
10:05	85.7	71.1	36.9	37.3	-1.2	53.0	51.7	2.5	56.5	55.7	1.3	48.0	48.0	0.0
10:10	85.7	71.3	38.1	37.3	2.2	51.9	51.2	1.4	55.8	55.8	-0.1	47.8	48.3	-1.1
10:15	85.5	71.3	35.8	35.3	1.4	52.0	51.2	1.5	57.6	57.5	0.2	49.2	49.6	-0.9
10:20	85.3	71.4	35.1	35.1	0.0	51.8	51.3	1.0	58.2	57.8	0.8	49.7	49.9	-0.4
10:25	88.5	76.0	36.5	36.2	0.8	54.2	53.3	1.8	60.9	59.9	1.6	52.1	51.6	0.8
10:30	91.2	80.3	37.3	37.0	0.8	56.0	54.7	2.2	62.9	61.9	1.6	53.6	53.0	1.0
10:35	90.8	80.3	37.2	37.0	0.7	55.7	54.8	1.5	62.6	61.7	1.4	53.2	52.7	1.0

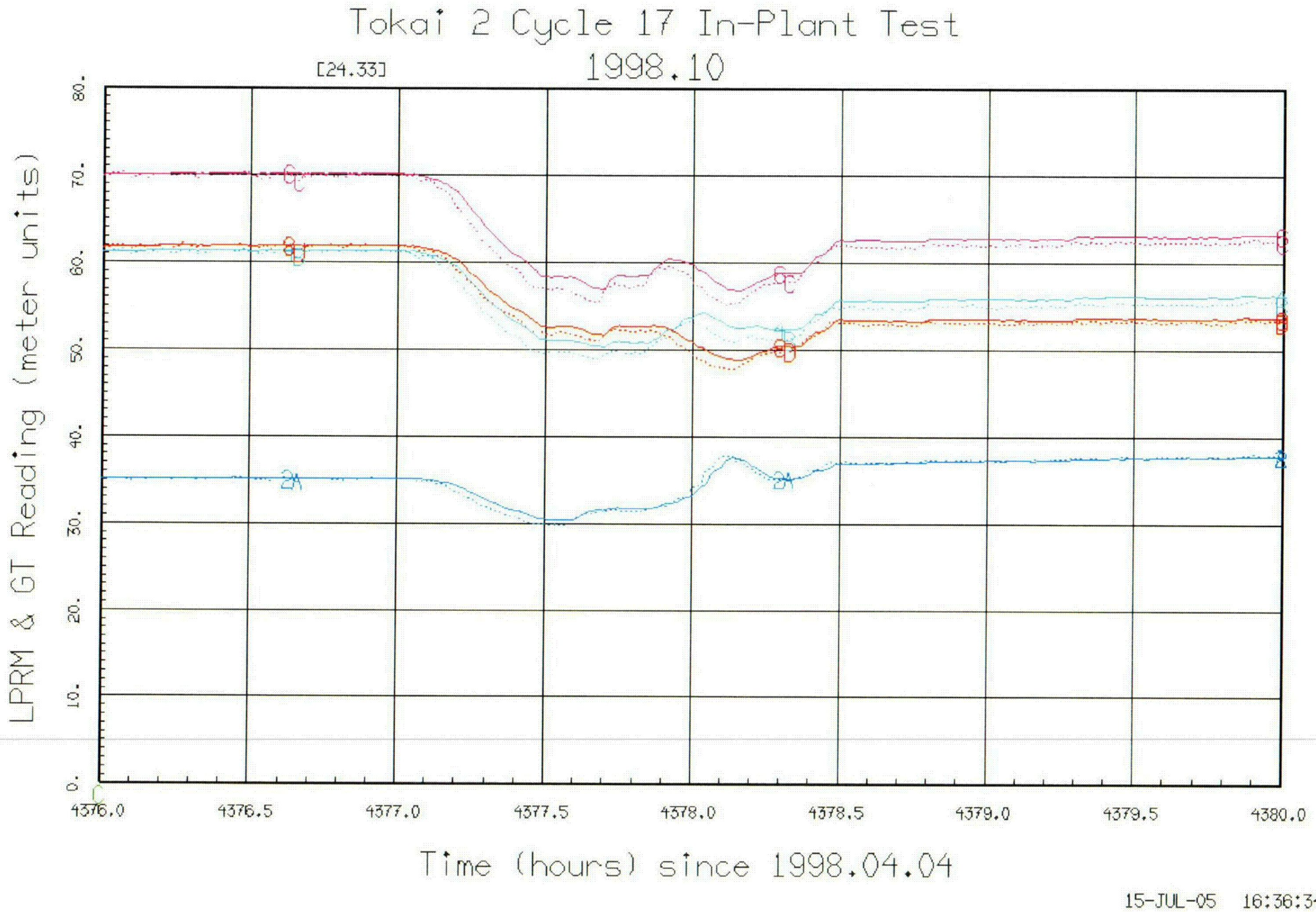
10:40	91.0	80.4	37.2	37.0	0.4	55.5	54.7	1.5	62.4	61.7	1.1	53.1	52.8	0.5
10:45	90.8	80.3	37.2	36.9	0.6	55.5	54.6	1.7	62.4	61.6	1.3	53.1	52.7	0.7
10:50	91.5	81.2	37.3	37.3	0.2	55.8	55.1	1.3	62.7	62.0	1.1	53.3	53.4	-0.1
11:00	91.3	81.3	37.6	37.3	0.7	56.0	54.8	2.1	62.8	62.0	1.3	53.3	53.1	0.3
11:30	91.6	82.1	37.8	37.6	0.6	56.2	55.2	1.8	63.0	62.4	1.1	53.4	53.3	0.3
12:00	92.3	82.9	38.0	37.8	0.5	56.3	55.4	1.7	63.2	62.5	1.2	53.5	53.3	0.4

Table 7-17, Comparison of Delayed Gamma Compensated GT with LPRM Readings for RSTK-02 (control blade pattern change)

Time	Pwr. %	Flow %	GT 2	LPRM A	% Diff.	GT 4	LPRM B	% Diff.	GT 6	LPRM C	% Diff.	GT 8	LPRM D	% Diff.
8:00	99.5	99.8	27.4	27.5	-0.1	66.8	67.0	-0.3	71.6	71.7	-0.2	61.7	61.8	-0.1
8:30	99.6	99.5	27.4	27.6	-0.6	66.8	67.2	-0.6	71.4	71.9	-0.7	61.5	61.8	-0.5
9:00	99.3	99.8	27.6	27.4	0.8	67.4	66.7	1.0	72.0	71.6	0.6	61.9	61.7	0.4
9:05	98.8	98.6	27.3	27.4	-0.5	66.6	66.5	0.2	71.2	71.0	0.3	61.3	61.3	0.0
9:10	96.9	95.1	27.1	26.9	0.7	65.7	65.0	1.0	70.2	69.6	0.8	60.5	60.1	0.7
9:15	91.6	87.1	25.8	25.7	0.7	61.8	61.3	0.8	66.2	65.6	0.8	57.3	57.0	0.6
9:20	87.2	79.8	24.8	24.7	0.3	58.6	58.2	0.7	62.5	62.2	0.5	54.5	54.4	0.2
9:25	84.3	75.1	24.0	23.9	0.3	56.4	56.3	0.3	60.1	60.0	0.1	52.4	52.6	-0.3
9:30	82.1	71.6	23.2	23.5	-1.4	54.3	54.6	-0.4	57.7	58.2	-0.8	50.5	51.2	-1.4
9:35	82.2	71.6	23.2	23.5	-1.0	54.6	54.8	-0.4	58.0	58.5	-0.9	50.8	51.3	-1.0
9:40	81.7	71.5	27.2	26.4	2.9	55.0	54.2	1.4	55.4	55.8	-0.8	49.4	49.8	-0.8
9:45	83.7	71.4	26.7	26.6	0.4	55.4	55.0	0.8	57.7	57.6	0.2	50.9	51.2	-0.6
9:50	83.4	71.5	26.6	26.4	0.7	55.2	54.6	1.0	57.4	57.5	-0.3	50.7	51.0	-0.6
9:55	85.8	71.0	27.2	27.2	-0.1	56.7	56.5	0.3	59.4	59.5	-0.1	51.1	50.6	1.0
10:00	86.3	71.1	27.9	27.7	0.6	58.9	57.9	1.9	59.1	58.9	0.5	49.0	49.0	0.0
10:05	85.7	71.1	29.5	29.9	-1.3	58.9	57.2	3.0	57.4	56.6	1.4	47.6	47.6	0.1
10:10	85.7	71.3	31.2	30.1	3.7	57.3	56.4	1.5	55.9	56.7	-1.4	46.9	47.8	-1.9
10:15	85.5	71.3	27.0	26.8	0.6	56.5	54.9	3.0	59.5	59.3	0.4	49.4	49.5	-0.2
10:20	85.3	71.4	26.1	26.0	0.1	50.6	51.0	-0.7	61.1	61.0	0.3	50.4	50.4	0.1
10:25	88.5	76.0	26.8	26.8	0.0	52.7	53.1	-0.8	63.8	63.6	0.4	52.8	52.8	-0.1
10:30	91.2	80.3	27.7	27.5	0.5	54.9	54.7	0.4	66.2	65.4	1.3	54.7	54.1	1.1
10:35	90.8	80.3	27.6	27.3	1.2	54.6	54.5	0.1	65.9	65.4	0.8	54.3	54.0	0.6

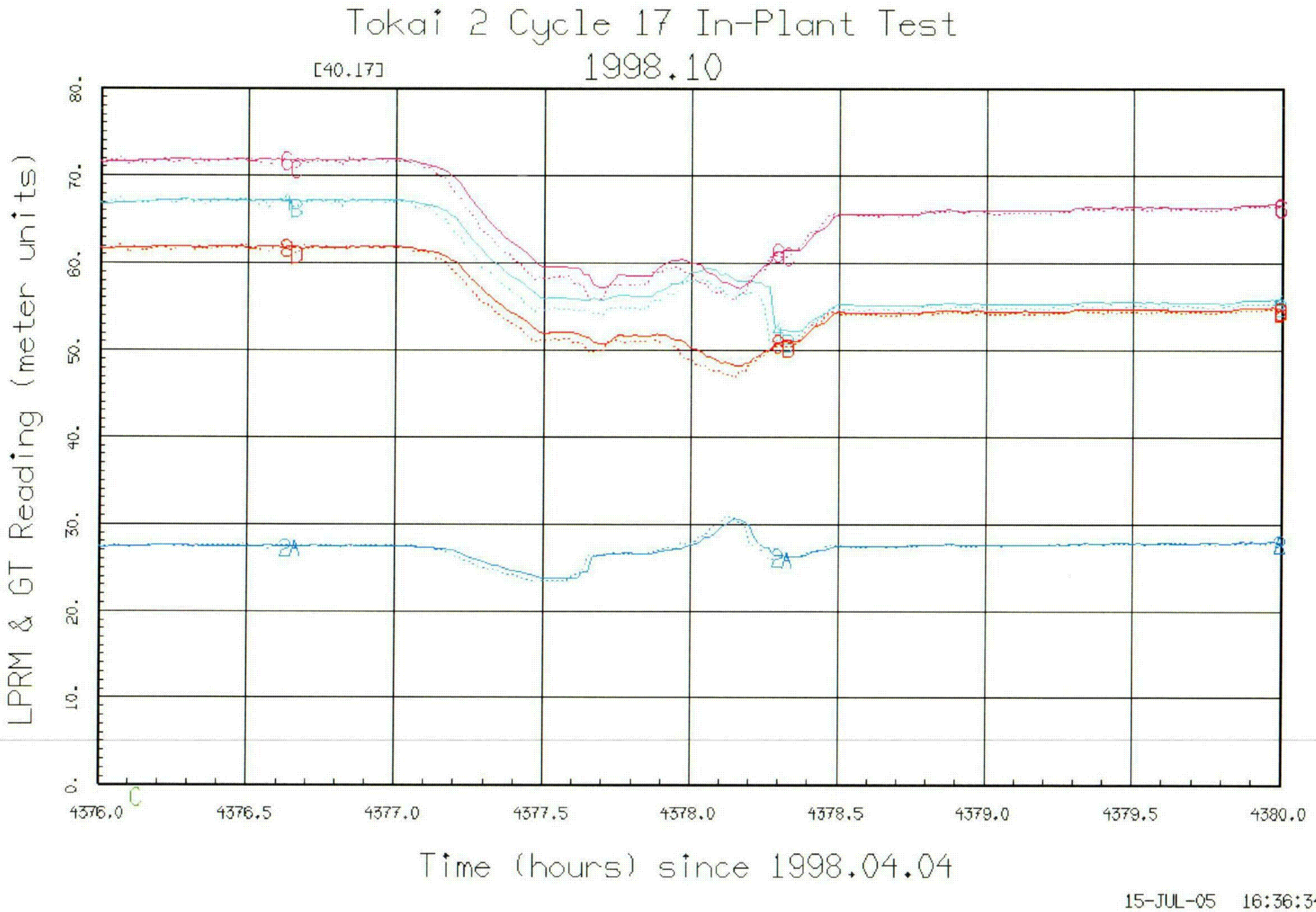
10:40	91.0	80.4	27.6	27.4	0.9	54.7	54.6	0.1	65.8	65.5	0.4	54.3	54.0	0.6
10:45	90.8	80.3	27.6	27.4	0.9	54.6	54.5	0.1	65.7	65.4	0.6	54.1	53.9	0.5
10:50	91.5	81.2	27.7	27.6	0.4	54.8	54.9	-0.1	66.2	65.9	0.4	54.5	54.2	0.5
11:00	91.3	81.3	27.7	27.6	0.4	54.8	54.6	0.5	66.0	65.7	0.5	54.3	54.2	0.1
11:30	91.6	82.1	27.8	27.7	0.1	55.1	55.2	-0.3	66.4	66.3	0.1	54.5	54.5	-0.1
12:00	92.3	82.9	27.9	27.9	0.1	55.2	55.1	0.1	66.5	66.5	0.1	54.6	54.6	0.0

Figure 7-59, Un-Compensated GT vs. LPRM Readings for RSTK-01 (CB move)



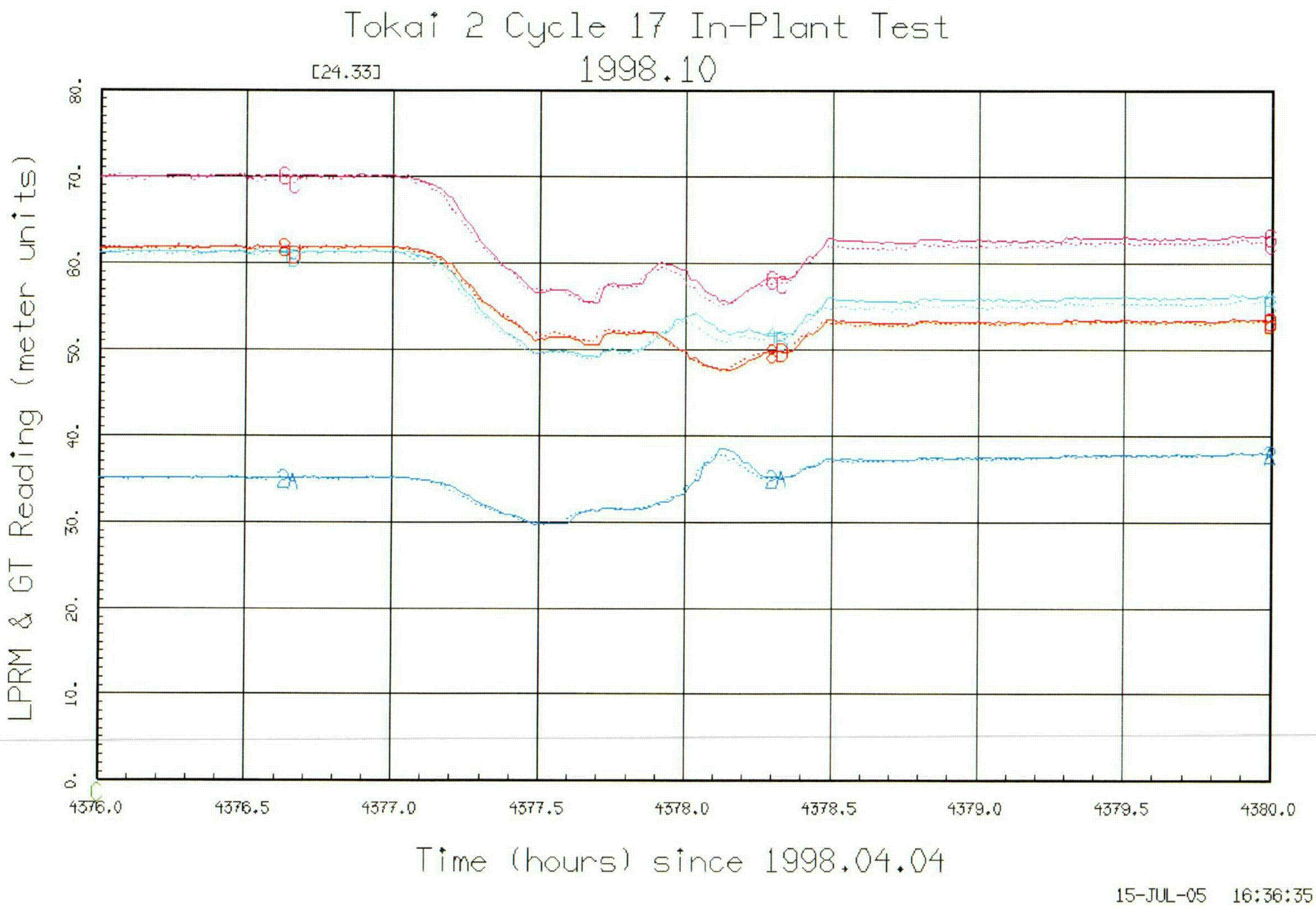
C21

Figure 7-60, Un-Compensated GT vs. LPRM Readings for RSTK-02 (CB move)



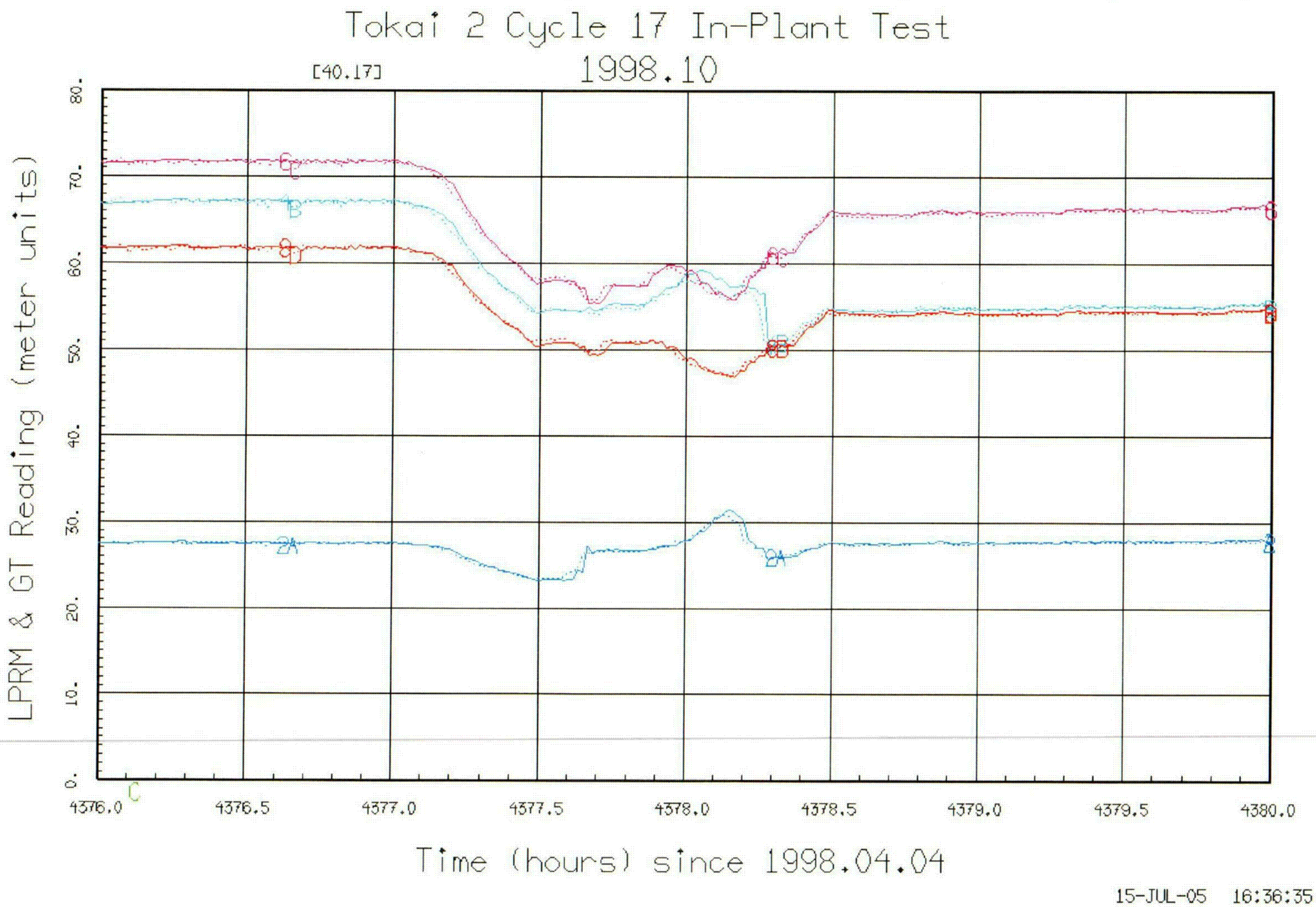
C22

Figure 7-61, Delayed Gamma Comp. GT vs. LPRM Readings for RSTK-01 (CB move)



C23

Figure 7-62, Delayed Gamma Comp. GT vs. LPRM Readings for RSTK-02 (CB move)



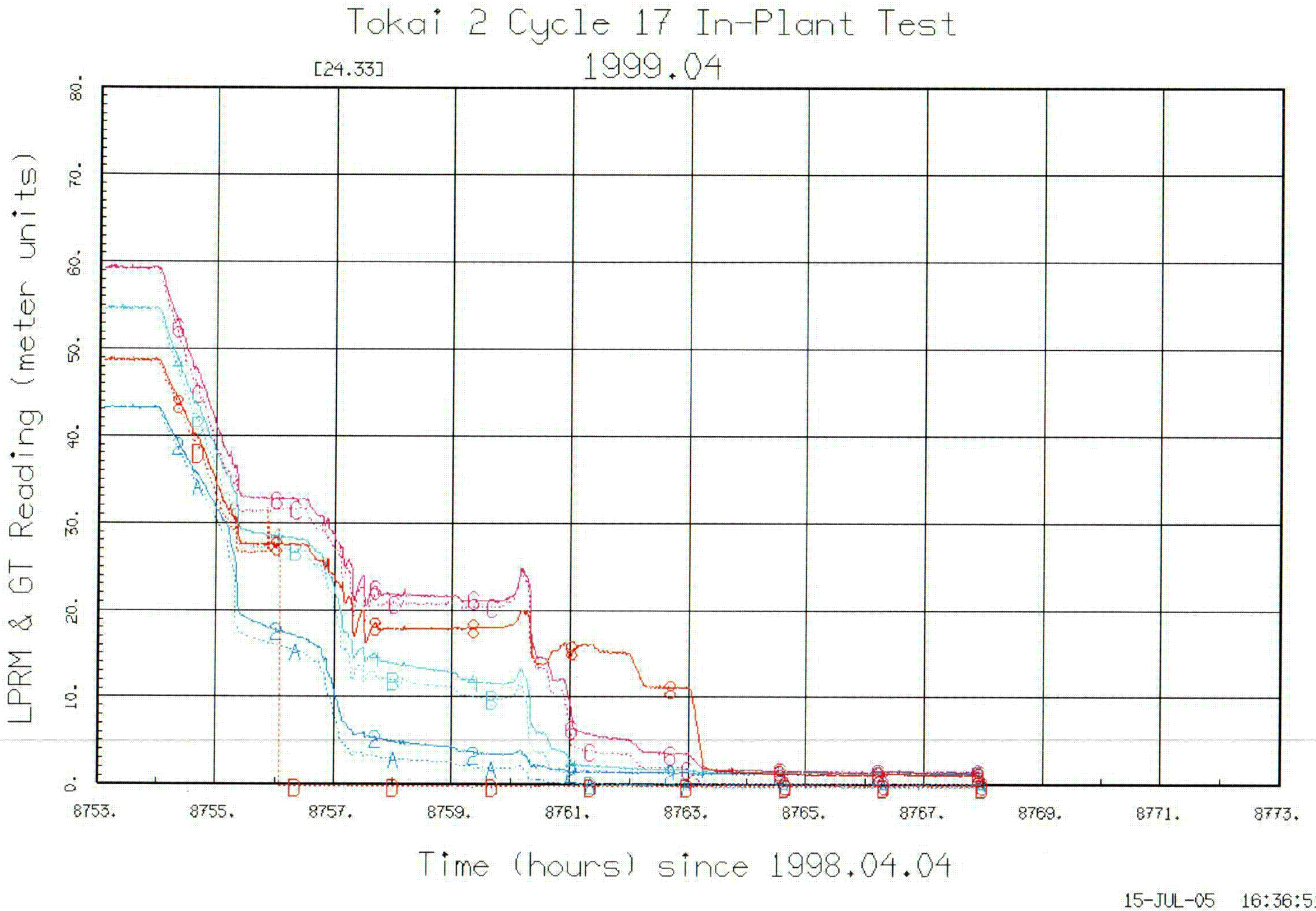
C24

7.2.6.4 Response During Power Down

[[

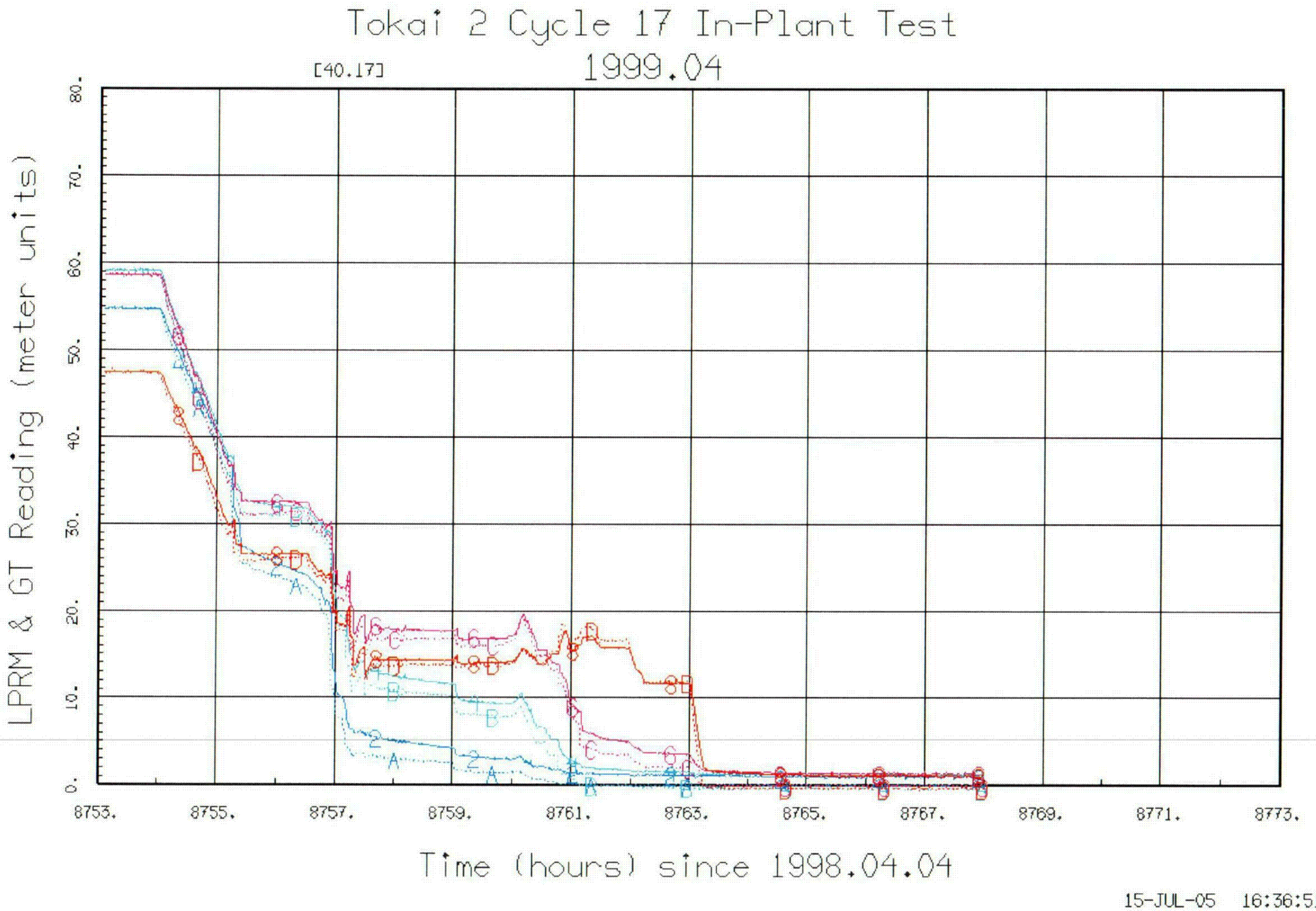
]]

Figure 7-63, Un-Compensated GT vs. LPRM Readings for RSTK-01 (power down)



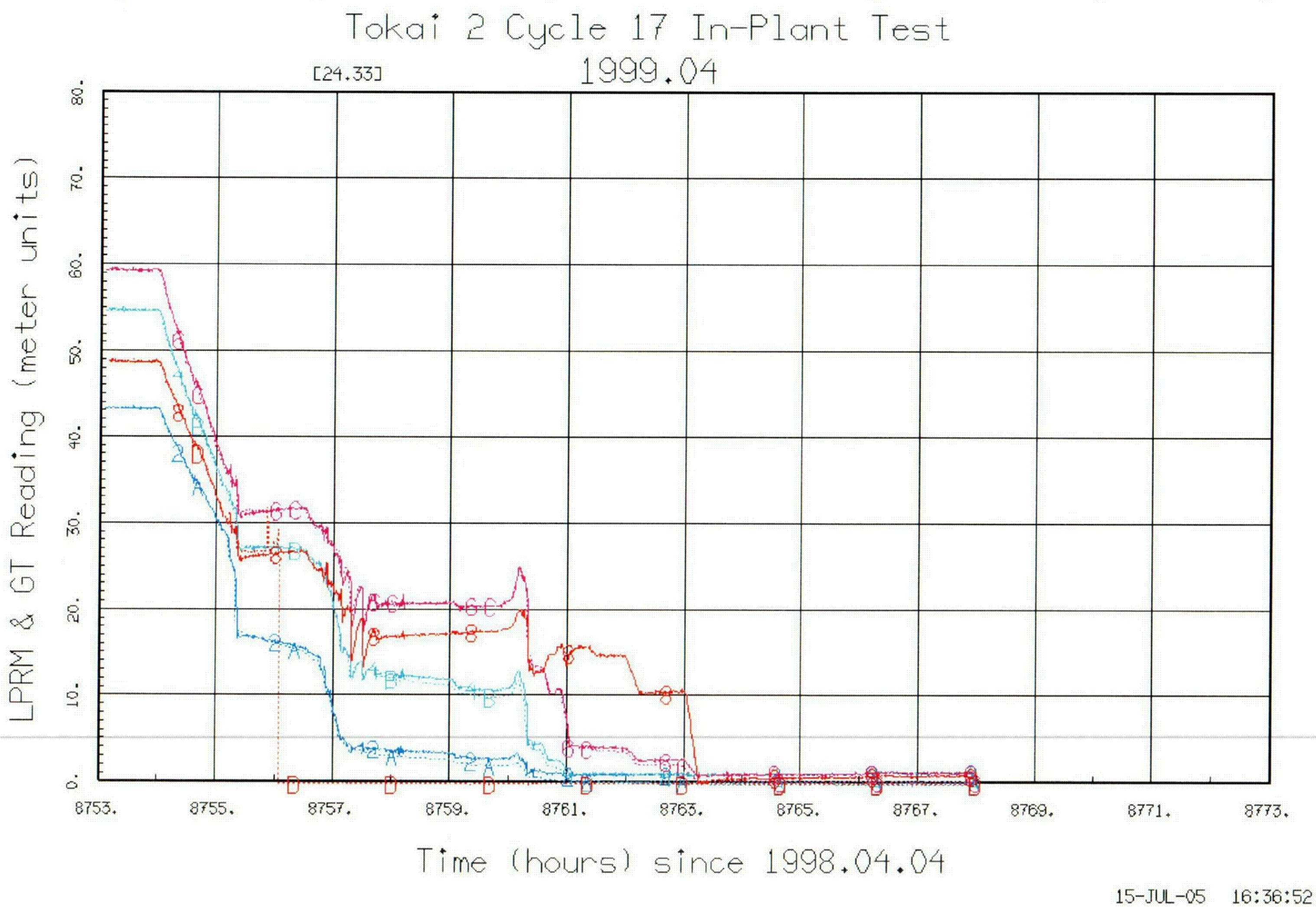
C25

Figure 7-64, Un-Compensated GT vs. LPRM Readings for RSTK-02 (power down)



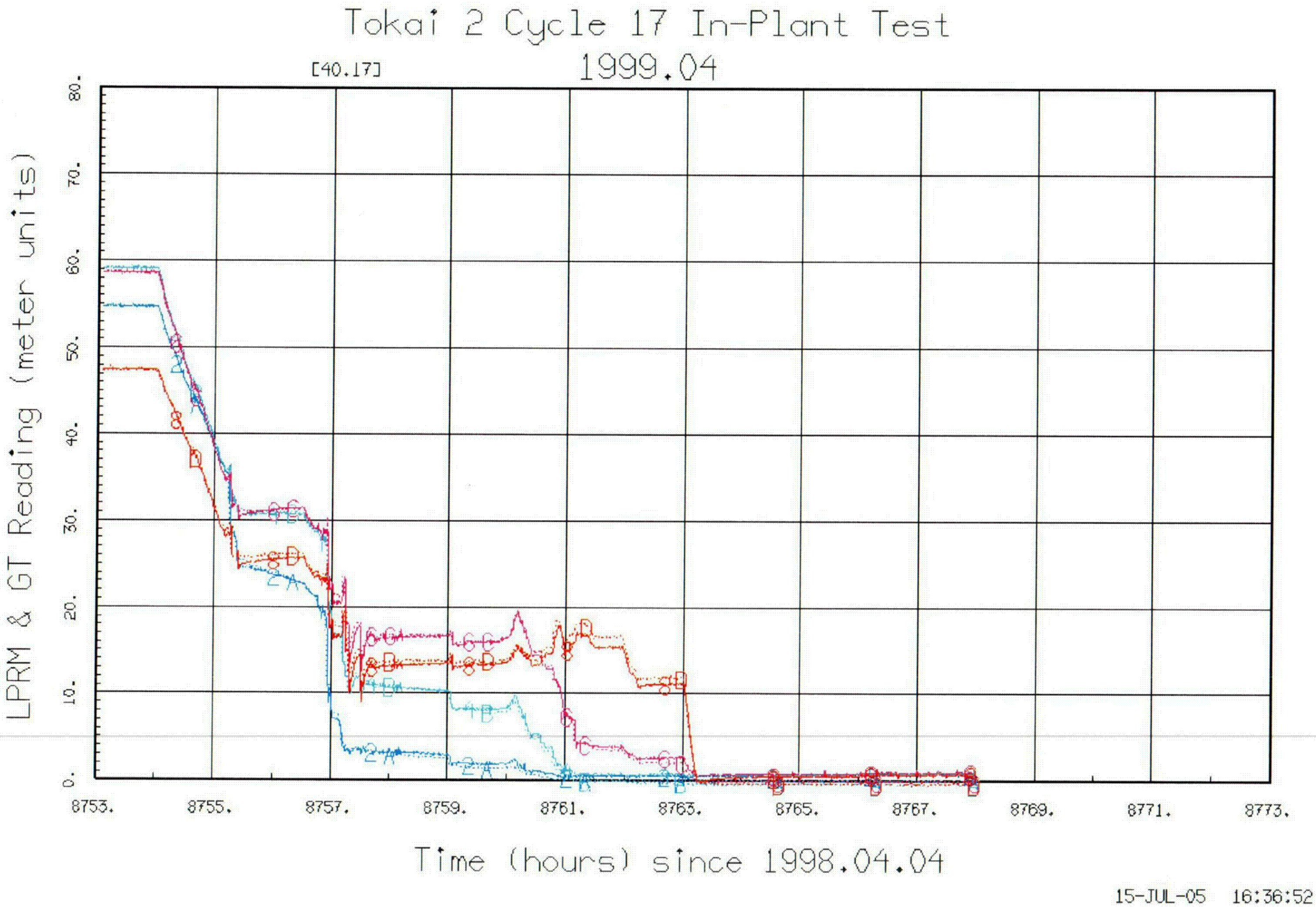
C26

Figure 7-65, Delayed Gamma Comp. GT vs. LPRM Readings for RSTK-01 (power down)



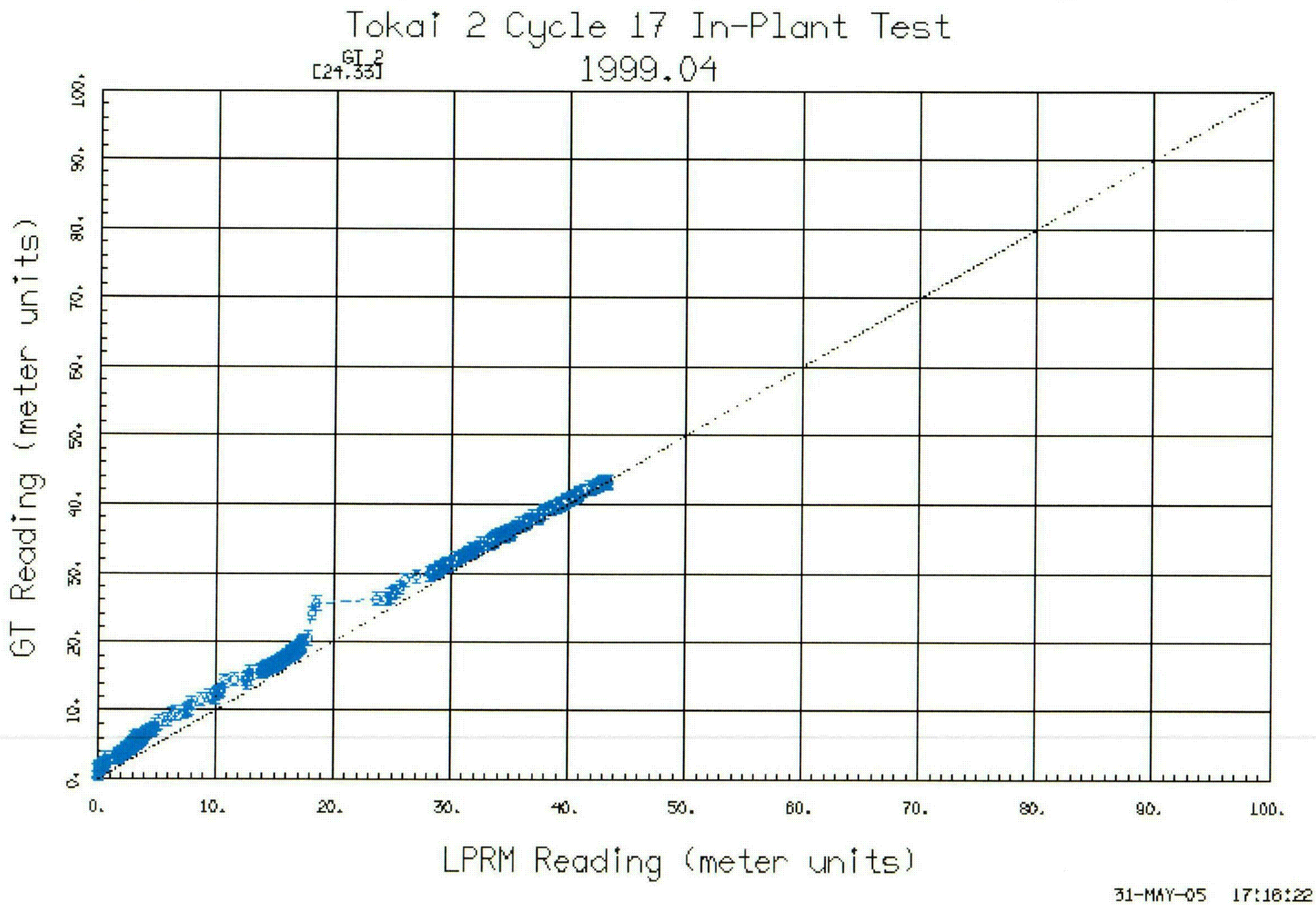
C27

Figure 7-66, Delayed Gamma Comp. GT vs. LPRM Readings for RSTK-02 (power down)



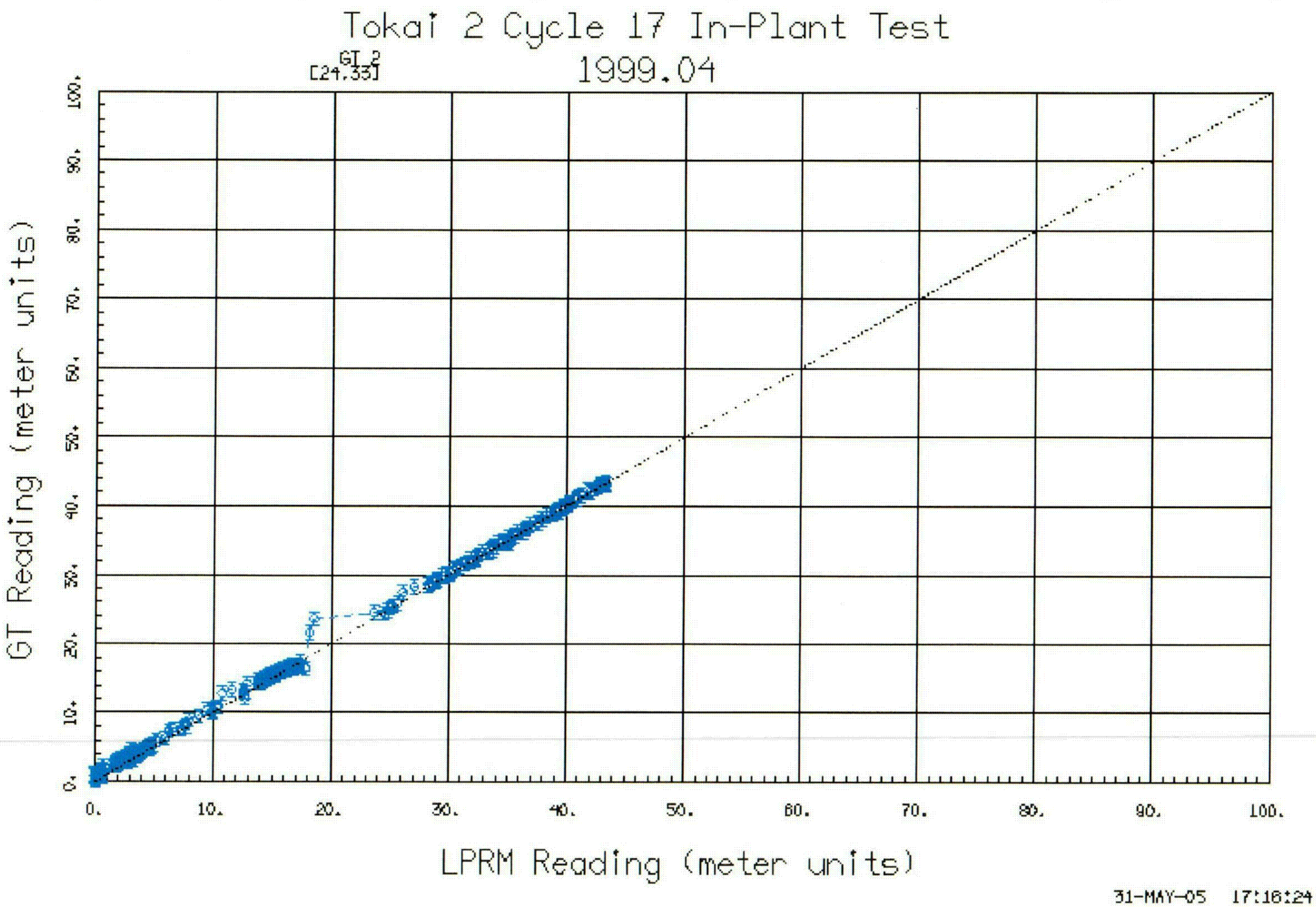
C28

Figure 7-67, Un-Compensated GT Linearity for Sensor 2 at RSTK-01 (power down)



C29

Figure 7-68, Delayed Gamma Comp. GT Linearity for Sensor 2 at RSTK-02 (power down)



C30

7.3 Kashiwazaki-Kariwa 5 In-Plant Test

The Kashiwazaki-Kariwa 5 plant is an 1100 MWe BWR5 operated by Tokyo Electric Power Company. The core has 764 bundles arranged in a "C" lattice configuration. The TIP system is neutron sensitive and has 43 calibration tubes and associated LPRM strings.

The research reported here was sponsored jointly by Tokyo Electric Power Company, Tohoku Electric Power Company, Chubu Electric Power Company, Hokuriku Electric Power Company, The Chugoku Electric Power Company, The Japan Atomic Power Company, Toshiba Corporation, Hitachi, Ltd. and Global Nuclear Fuel – Japan (see reference 4).

7.3.1 Test Plan

The test plan was to install 8 LPRM/GT assemblies (4 each from two separate suppliers) into an octant of the core. A comprehensive core monitoring study would therefore be possible, subject only to the condition of octant symmetry. Standard TIP calibration tubes were installed in the LPRM/GT assemblies so that normal TIP set measurements could be taken.

In order to assess the accuracy of core monitoring with GT readings, a bundle gamma scan was to be performed at the end of one cycle of operation. The scan was to include all of the bundles in the octant of the core as well as three additional bundles chosen so that all four bundles around each LPRM/GT assembly were included.

In addition, comparisons of core monitoring results between the GT and the neutron TIP systems were to be made throughout the cycle.

The LPRM/GT assemblies were to have nine sensors each, arranged in a manner similar to the Tokai 2 In-Plant test. The core locations for the assemblies are shown in Figure 7-69.

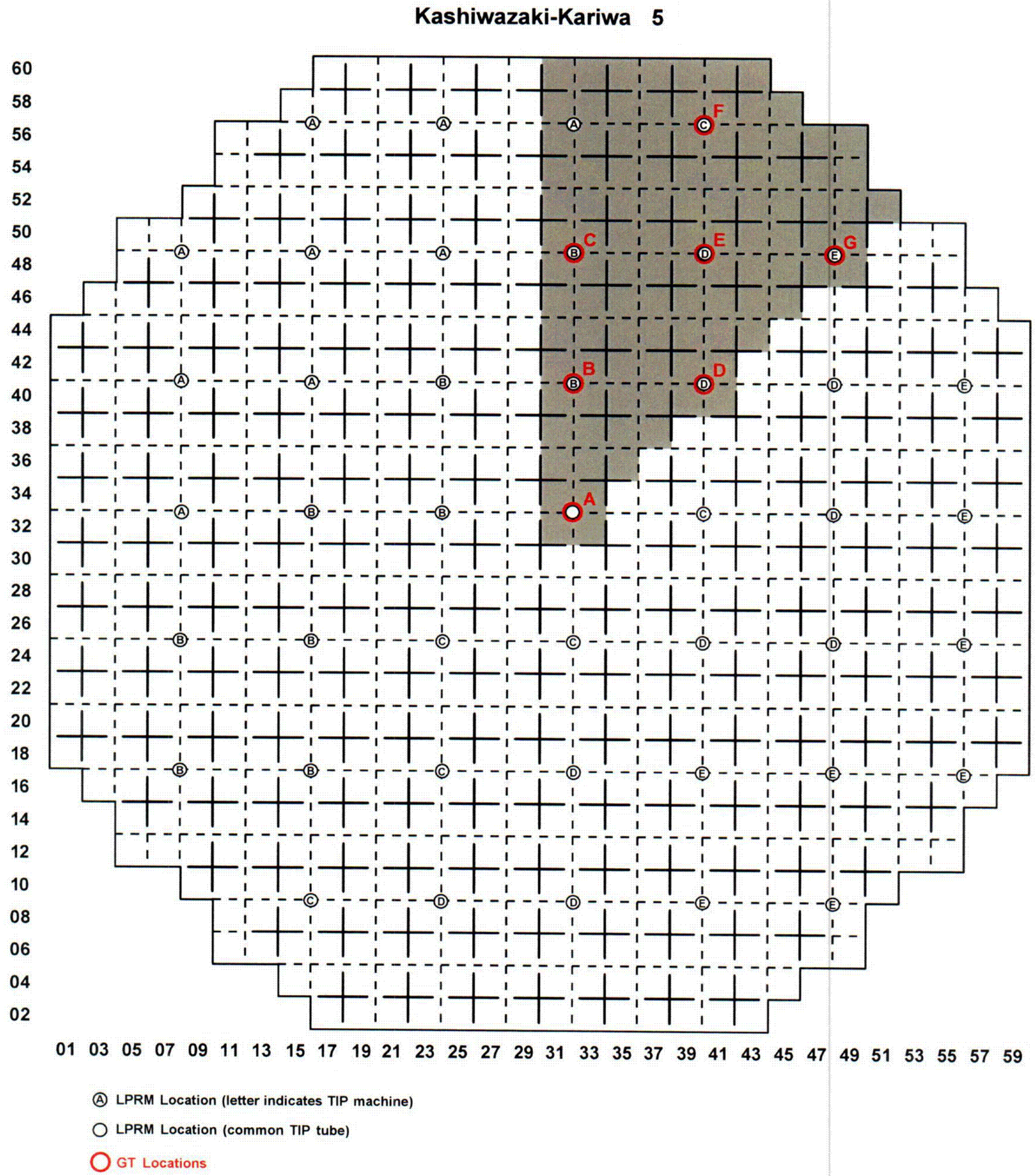


Figure 7-69, Kashiwazaki-Kariwa 5 Core Map

7.3.2 Test Results

The gamma scan measured the strong photo peak of ^{140}La the short-lived daughter of the common fission product ^{140}Ba. Measurements were taken at 17 axial locations, generally every six inches, but excluding nodes obscured by spacers and excluding the top and bottom nodes. The ^{140}Ba distribution was calculated by an off-line core monitoring system throughout the cycle

on a time interval of every 3 days. TIP adaptive core monitoring calculations were made 36 times during the cycle for the standard simulation. An equal number of GT adaptive calculations were made for the GT core monitoring simulation. Data were available only for seven of the eight GT assemblies[2], but this did not significantly detract from the results of the study.

The results showed very good agreement between the calculated and measured ^{140}Ba distributions for both the GT adaptive monitoring and the TIP adaptive monitoring. Table 7-18 shows the RMS differences between the calculated and measured distributions as measured for the 1D (axial) distribution, for the 2D (bundle) radial distribution and for the 3D (nodal) distribution.

Table 7-18, RMS Differences between Calculated and Measured ^{140}Ba Distributions

Distribution	n TIP vs. γ Scan	GT vs. γ Scan
1D (axial)	1.7%	2.1%
2D (bundle)	2.5%	2.3%
3D (nodal)	3.9%	4.1%

In addition to the gamma scan studies, comparisons were also made between the thermal limits calculated by the two core monitors. The RMS difference for the whole cycle between the MCPR calculated by the GT core monitor and the MCPR calculated by the neutron TIP monitor was 0.008. The maximum difference was 0.02.

Similarly, the RMS difference between the MLHGR calculated by the GT core monitor and the MLHGR calculated by the neutron TIP was 0.4 KW/m and the maximum difference was 1 KW/m.

7.3.3 Conclusions

The comparison with the gamma scan established that core monitoring based on GTs is nearly equivalent in accuracy to core monitoring with neutron TIPs. In addition, it was shown that the thermal limits, MCPR and MLHGR, evaluated by the two core monitoring systems were very similar throughout the cycle.

The overall conclusion was that the GT system is "practical as a substitute" for the TIP system.

[2] According to a personal communication, one of the assemblies planned for the test experienced a failure that affected all nine sensors in the assembly. Modern core monitors such as 3DMonicore are tolerant of this type of fault and are able to produce accurate results with several assemblies out of service.

8. ADAPTIVE CORE MONITORING SIMULATION

[[

]]

[3] [[

]]

[[

]]

[[

]]

8.1 Power Distribution Comparison

[[

]]

Table 8-1, Axial Power Distributions from TIP and GT Adaption for RSTK-01 at 9:04 on 1998/04/06 at 29.2% Power

	Location (23,34)			Location (25,34)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.205	0.197	-0.8	0.234	0.231	-0.3
23	0.535	0.544	0.9	0.660	0.673	1.2
22	0.766	0.758	-0.7	0.962	0.959	-0.3
21	0.943	0.951	0.8	1.165	1.181	1.6
20	1.125	1.133	0.8	1.316	1.326	1.0
19	1.298	1.263	-3.5	1.514	1.476	-3.7
18	1.456	1.401	-5.5	1.696	1.639	-5.8
17	1.605	1.557	-4.8	1.879	1.826	-5.3
16	1.806	1.728	-7.7	2.113	2.031	-8.2
15	1.966	1.903	-6.2	2.309	2.247	-6.2
14	2.088	2.067	-2.1	2.472	2.460	-1.3
13	2.247	2.206	-4.1	2.686	2.646	-4.0
12	2.357	2.303	-5.3	2.849	2.799	-4.9
11	2.384	2.318	-6.6	2.944	2.885	-5.9
10	2.090	2.084	-0.6	2.732	2.741	1.0
9	1.854	1.815	-3.9	2.411	2.377	-3.5
8	1.478	1.404	-7.4	1.619	1.548	-7.1
7	1.089	1.044	-4.6	1.047	1.006	-4.0
6	0.800	0.768	-3.2	0.727	0.701	-2.6
5	0.580	0.564	-1.7	0.512	0.500	-1.2
4	0.414	0.417	0.4	0.360	0.366	0.6
3	0.290	0.305	1.5	0.249	0.263	1.4
2	0.193	0.200	0.7	0.159	0.167	0.7
1	0.059	0.056	-0.3	0.040	0.039	-0.2
Bundle:	1.234	1.208	-2.2	1.444	1.420	-1.6

Table 8-1, Axial Power Distributions from TIP and GT Adaption for RSTK-01 at 9:04 on 1998/04/06 at 29.2% Power (continued)

	Location (23,32)			Location (25,32)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.191	0.186	-0.5	0.232	0.233	0.1
23	0.468	0.477	0.9	0.601	0.614	1.3
22	0.590	0.585	-0.5	0.790	0.790	0.0
21	0.687	0.694	0.7	0.935	0.951	1.6
20	0.791	0.798	0.7	1.092	1.104	1.2
19	0.888	0.865	-2.3	1.241	1.214	-2.7
18	0.981	0.946	-3.5	1.383	1.341	-4.2
17	1.069	1.040	-2.9	1.524	1.488	-3.6
16	1.179	1.130	-4.9	1.697	1.636	-6.1
15	1.270	1.233	-3.7	1.845	1.803	-4.3
14	1.341	1.333	-0.9	1.968	1.967	-0.1
13	1.405	1.383	-2.2	2.101	2.078	-2.3
12	1.435	1.404	-3.1	2.191	2.158	-3.2
11	1.426	1.386	-4.0	2.229	2.190	-3.9
10	1.239	1.239	0.0	2.019	2.036	1.7
9	1.056	1.033	-2.3	1.784	1.763	-2.1
8	0.838	0.792	-4.6	1.388	1.325	-6.3
7	0.620	0.593	-2.6	0.995	0.957	-3.8
6	0.444	0.428	-1.7	0.697	0.675	-2.2
5	0.316	0.308	-0.9	0.489	0.479	-1.0
4	0.229	0.233	0.4	0.349	0.357	0.8
3	0.171	0.181	1.0	0.255	0.271	1.5
2	0.129	0.135	0.6	0.183	0.193	1.0
1	0.039	0.037	-0.2	0.053	0.052	-0.1
Bundle:	0.784	0.768	-2.0	1.169	1.153	-1.3

Table 8-2, Axial Power Distributions from TIP and GT Adaption for RSTK-02 at 9:04 on 1998/04/06 at 29.2% Power

	Location (39,18)			Location (41,18)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.195	0.209	1.4	0.229	0.246	1.7
23	0.526	0.585	5.8	0.546	0.607	6.1
22	0.759	0.794	3.5	0.713	0.749	3.6
21	0.936	0.976	4.1	0.838	0.877	3.9
20	1.103	1.159	5.6	0.951	1.004	5.2
19	1.267	1.296	3.0	1.075	1.103	2.8
18	1.441	1.438	-0.3	1.218	1.218	0.0
17	1.579	1.584	0.5	1.326	1.335	0.9
16	1.746	1.735	-1.1	1.443	1.438	-0.5
15	1.864	1.890	2.6	1.534	1.558	2.4
14	1.975	2.037	6.2	1.627	1.679	5.2
13	2.102	2.152	5.0	1.690	1.734	4.4
12	2.167	2.213	4.6	1.718	1.757	3.9
11	2.134	2.177	4.3	1.682	1.717	3.4
10	1.874	1.921	4.8	1.497	1.537	4.0
9	1.676	1.679	0.3	1.324	1.327	0.3
8	1.444	1.415	-2.9	1.126	1.104	-2.3
7	1.174	1.152	-2.2	0.916	0.900	-1.6
6	0.941	0.908	-3.4	0.731	0.707	-2.5
5	0.738	0.708	-3.0	0.576	0.553	-2.2
4	0.561	0.558	-0.4	0.453	0.451	-0.2
3	0.417	0.432	1.6	0.358	0.373	1.5
2	0.279	0.299	2.0	0.267	0.287	2.0
1	0.078	0.081	0.3	0.084	0.088	0.4
Bundle:	1.207	1.225	1.5	0.997	1.015	1.8

Table 8-2, Axial Power Distributions from TIP and GT Adaption for RSTK-02 at 9:04 on 1998/04/06 at 29.2% Power (continued)

	Location (39,16)			Location (41,16)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.173	0.186	1.3	0.182	0.197	1.5
23	0.458	0.510	5.2	0.495	0.551	5.6
22	0.608	0.638	3.0	0.711	0.748	3.7
21	0.722	0.755	3.3	0.876	0.918	4.2
20	0.830	0.874	4.3	1.032	1.089	5.7
19	0.935	0.959	2.4	1.182	1.215	3.3
18	1.056	1.056	0.0	1.343	1.346	0.3
17	1.147	1.154	0.7	1.470	1.482	1.3
16	1.256	1.250	-0.5	1.628	1.625	-0.3
15	1.335	1.357	2.2	1.741	1.772	3.1
14	1.413	1.462	4.9	1.846	1.911	6.5
13	1.483	1.522	3.9	1.958	2.014	5.6
12	1.513	1.548	3.5	2.010	2.057	4.8
11	1.477	1.509	3.3	1.958	2.000	4.2
10	1.296	1.333	3.7	1.687	1.735	4.8
9	1.129	1.132	0.4	1.484	1.491	0.7
8	0.936	0.919	-1.7	1.261	1.240	-2.2
7	0.744	0.732	-1.1	1.020	1.004	-1.6
6	0.584	0.565	-1.9	0.820	0.793	-2.7
5	0.453	0.436	-1.8	0.649	0.624	-2.5
4	0.352	0.350	-0.1	0.499	0.497	-0.1
3	0.273	0.284	1.1	0.374	0.391	1.7
2	0.197	0.212	1.5	0.255	0.274	2.0
1	0.051	0.053	0.2	0.071	0.075	0.4
Bundle:	0.851	0.867	1.8	1.106	1.127	1.9

Table 8-3, Axial Power Distributions from TIP and GT Adaption for RSTK-01 at 15:48 on 1998/04/13 at 99.7% Power

	Location (23,34)			Location (25,34)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.282	0.280	-0.2	0.305	0.308	0.2
23	0.764	0.759	-0.5	0.867	0.859	-0.8
22	1.037	1.005	-3.2	1.189	1.155	-3.4
21	1.198	1.196	-0.2	1.352	1.353	0.0
20	1.322	1.334	1.2	1.431	1.443	1.2
19	1.380	1.362	-1.9	1.509	1.488	-2.1
18	1.391	1.370	-2.1	1.529	1.513	-1.6
17	1.383	1.379	-0.4	1.529	1.532	0.3
16	1.398	1.391	-0.7	1.544	1.548	0.3
15	1.388	1.405	1.7	1.535	1.563	2.8
14	1.353	1.412	5.9	1.499	1.575	7.6
13	1.376	1.413	3.6	1.524	1.574	5.0
12	1.411	1.412	0.1	1.560	1.572	1.2
11	1.369	1.414	4.6	1.514	1.579	6.5
10	1.287	1.353	6.6	1.465	1.551	8.6
9	1.278	1.360	8.2	1.463	1.562	9.9
8	1.322	1.373	5.1	1.516	1.581	6.6
7	1.317	1.386	7.0	1.523	1.609	8.6
6	1.354	1.382	2.7	1.576	1.612	3.6
5	1.376	1.356	-2.0	1.618	1.598	-2.0
4	1.307	1.303	-0.5	1.565	1.565	0.1
3	1.139	1.160	2.2	1.380	1.406	2.7
2	0.869	0.866	-0.3	1.013	1.014	0.1
1	0.280	0.259	-2.2	0.309	0.292	-1.7
Bundle:	1.191	1.205	1.2	1.347	1.369	1.7

Table 8-3, Axial Power Distributions from TIP and GT Adaption for RSTK-01 at 15:48 on 1998/04/13 at 99.7% Power (continued)

	Location (23,32)			Location (25,32)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.334	0.337	0.3	0.322	0.331	0.9
23	0.828	0.826	-0.2	0.839	0.835	-0.5
22	1.029	1.002	-2.7	1.050	1.025	-2.6
21	1.136	1.138	0.3	1.170	1.176	0.6
20	1.210	1.226	1.6	1.272	1.288	1.6
19	1.247	1.235	-1.2	1.332	1.319	-1.3
18	1.254	1.238	-1.6	1.350	1.340	-0.9
17	1.244	1.243	-0.1	1.350	1.356	0.6
16	1.238	1.236	-0.2	1.352	1.360	0.8
15	1.225	1.242	1.8	1.344	1.372	2.9
14	1.196	1.251	5.5	1.314	1.385	7.1
13	1.193	1.229	3.6	1.321	1.371	4.9
12	1.208	1.210	0.2	1.346	1.358	1.2
11	1.169	1.209	4.1	1.302	1.362	6.0
10	1.123	1.184	6.1	1.252	1.331	7.9
9	1.100	1.171	7.1	1.238	1.325	8.7
8	1.121	1.164	4.3	1.268	1.325	5.7
7	1.110	1.171	6.1	1.262	1.338	7.6
6	1.115	1.140	2.5	1.278	1.312	3.3
5	1.116	1.100	-1.6	1.290	1.276	-1.5
4	1.078	1.077	0.0	1.249	1.255	0.6
3	0.998	1.018	2.0	1.153	1.177	2.4
2	0.843	0.842	-0.2	0.954	0.956	0.2
1	0.290	0.270	-2.0	0.296	0.282	-1.5
Bundle:	1.059	1.073	1.4	1.163	1.186	2.0

Table 8-4, Axial Power Distributions from TIP and GT Adaption for RSTK-02 at 15:48 on 1998/04/13 at 99.7% Power

	Location (39,18)			Location (41,18)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.294	0.271	-2.3	0.333	0.306	-2.7
23	0.753	0.750	-0.2	0.730	0.725	-0.5
22	1.023	0.981	-4.2	0.906	0.869	-3.8
21	1.166	1.155	-1.2	0.993	0.983	-1.0
20	1.271	1.282	1.0	1.052	1.062	0.9
19	1.347	1.311	-3.6	1.113	1.084	-2.9
18	1.369	1.323	-4.6	1.141	1.105	-3.5
17	1.353	1.336	-1.7	1.129	1.121	-0.9
16	1.388	1.353	-3.5	1.146	1.123	-2.3
15	1.383	1.375	-0.8	1.141	1.139	-0.3
14	1.342	1.393	5.2	1.109	1.157	4.9
13	1.372	1.403	3.2	1.110	1.143	3.2
12	1.413	1.409	-0.4	1.134	1.134	0.0
11	1.374	1.413	3.9	1.095	1.131	3.6
10	1.290	1.353	6.3	1.041	1.097	5.6
9	1.291	1.356	6.5	1.024	1.078	5.3
8	1.314	1.369	5.5	1.025	1.069	4.4
7	1.308	1.390	8.2	1.009	1.074	6.5
6	1.356	1.400	4.4	1.018	1.053	3.5
5	1.376	1.394	1.7	1.012	1.023	1.1
4	1.329	1.357	2.8	0.980	0.999	1.9
3	1.199	1.219	2.0	0.915	0.932	1.6
2	0.923	0.912	-1.1	0.773	0.762	-1.1
1	0.290	0.256	-3.4	0.274	0.242	-3.2
Bundle:	1.189	1.198	0.8	0.967	0.975	0.9

Table 8-4, Axial Power Distributions from TIP and GT Adaption for RSTK-02 at 15:48 on 1998/04/13 at 99.7% Power (continued)

	Location (39,16)			Location (41,16)		
Axial Node	TIP Power	GT Power	Diff. (rd)	TIP Power	GT Power	Diff. (rd)
24	0.325	0.301	-2.4	0.263	0.243	-2.1
23	0.790	0.786	-0.4	0.677	0.672	-0.6
22	1.014	0.972	-4.2	0.919	0.880	-3.9
21	1.123	1.112	-1.2	1.055	1.044	-1.1
20	1.210	1.217	0.7	1.172	1.180	0.8
19	1.285	1.250	-3.5	1.272	1.237	-3.5
18	1.320	1.276	-4.4	1.321	1.279	-4.2
17	1.314	1.295	-1.9	1.326	1.312	-1.4
16	1.340	1.307	-3.2	1.369	1.340	-2.8
15	1.335	1.328	-0.7	1.371	1.368	-0.3
14	1.299	1.349	5.0	1.333	1.391	5.8
13	1.315	1.346	3.0	1.365	1.404	3.8
12	1.348	1.345	-0.2	1.411	1.411	0.0
11	1.312	1.352	4.0	1.368	1.414	4.7
10	1.262	1.325	6.3	1.282	1.352	7.0
9	1.262	1.324	6.2	1.285	1.350	6.5
8	1.276	1.331	5.5	1.300	1.357	5.7
7	1.275	1.355	8.0	1.287	1.370	8.3
6	1.315	1.356	4.0	1.327	1.370	4.3
5	1.339	1.351	1.2	1.344	1.354	1.0
4	1.331	1.358	2.7	1.289	1.315	2.5
3	1.267	1.290	2.2	1.162	1.185	2.3
2	1.045	1.034	-1.1	0.906	0.896	-1.1
1	0.336	0.300	-3.6	0.285	0.255	-3.1
Bundle:	1.168	1.177	0.8	1.154	1.166	1.0

Table 8-5, TIP and GT Adaption Difference Summary for RSTK-01

	Location:	(23,34)	(25,34)
RMS (rd)	Pwr.		
Mean	< 95%	3.5	3.7
Standard Dev.	< 95%	0.5	0.5
Standard Error	< 95%	0.3	0.3
Mean	≥ 95%	3.8	4.3
Standard Dev.	≥ 95%	0.2	0.2
Standard Error	≥ 95%	0.1	0.1
Mean	All	3.7	4.1
Standard Dev.	All	0.3	0.4
Standard Error	All	0.1	0.1
Peak to Peak (%)	Pwr.		
Mean	< 95%	-1.3	-0.6
Standard Dev.	< 95%	0.9	0.9
Standard Error	< 95%	0.5	0.5
Mean	≥ 95%	-0.4	0.3
Standard Dev.	≥ 95%	0.8	1.0
Standard Error	≥ 95%	0.2	0.3
Mean	All	-0.6	0.1
Standard Dev.	All	0.9	1.0
Standard Error	All	0.2	0.3
Bundle (%)	Pwr.		
Mean	< 95%	-0.1	0.3
Standard Dev.	< 95%	1.2	1.2
Standard Error	< 95%	0.7	0.7
Mean	≥ 95%	1.0	1.3
Standard Dev.	≥ 95%	0.2	0.2
Standard Error	≥ 95%	0.1	0.1
Mean	All	0.7	1.1
Standard Dev.	All	0.8	0.7
Standard Error	All	0.2	0.2

Table 8-5, TIP and GT Adaption Difference Summary for RSTK-01 (continued)

	Location:	(23,32)	(25,32)
RMS (rd)	Pwr.		
Mean	< 95%	2.7	3.2
Standard Dev.	< 95%	0.4	0.5
Standard Error	< 95%	0.2	0.3
Mean	≥ 95%	3.1	3.8
Standard Dev.	≥ 95%	0.1	0.2
Standard Error	≥ 95%	0.0	0.0
Mean	All	3.0	3.6
Standard Dev.	All	0.3	0.4
Standard Error	All	0.1	0.1
Peak to Peak (%)	Pwr.		
Mean	< 95%	-1.0	-0.4
Standard Dev.	< 95%	0.9	0.8
Standard Error	< 95%	0.5	0.5
Mean	≥ 95%	-0.9	0.8
Standard Dev.	≥ 95%	0.9	1.0
Standard Error	≥ 95%	0.3	0.3
Mean	All	-0.9	0.6
Standard Dev.	All	0.9	1.1
Standard Error	All	0.2	0.3
Bundle (%)	Pwr.		
Mean	< 95%	0.0	0.5
Standard Dev.	< 95%	1.2	1.1
Standard Error	< 95%	0.7	0.6
Mean	≥ 95%	1.1	1.6
Standard Dev.	≥ 95%	0.2	0.2
Standard Error	≥ 95%	0.1	0.1
Mean	All	0.9	1.4
Standard Dev.	All	0.7	0.7
Standard Error	All	0.2	0.2

Table 8-6, TIP and GT Adaption Difference Summary for RSTK-02

	Location:	(39,18)	(41,18)
RMS (rd)	Pwr.		
Mean	< 95%	3.5	2.9
Standard Dev.	< 95%	0.6	0.3
Standard Error	< 95%	0.3	0.2
Mean	≥ 95%	4.0	3.2
Standard Dev.	≥ 95%	0.6	0.4
Standard Error	≥ 95%	0.2	0.1
Mean	All	3.9	3.1
Standard Dev.	All	0.6	0.4
Standard Error	All	0.2	0.1
Peak to Peak (%)	Pwr.		
Mean	< 95%	1.3	1.5
Standard Dev.	< 95%	0.8	1.1
Standard Error	< 95%	0.4	0.7
Mean	≥ 95%	1.0	1.8
Standard Dev.	≥ 95%	1.0	1.0
Standard Error	≥ 95%	0.3	0.3
Mean	All	1.1	1.7
Standard Dev.	All	0.9	1.1
Standard Error	All	0.2	0.3
Bundle (%)	Pwr.		
Mean	< 95%	1.0	1.1
Standard Dev.	< 95%	0.5	0.5
Standard Error	< 95%	0.3	0.3
Mean	≥ 95%	1.1	1.2
Standard Dev.	≥ 95%	0.4	0.4
Standard Error	≥ 95%	0.1	0.1
Mean	All	1.1	1.2
Standard Dev.	All	0.4	0.5
Standard Error	All	0.1	0.1

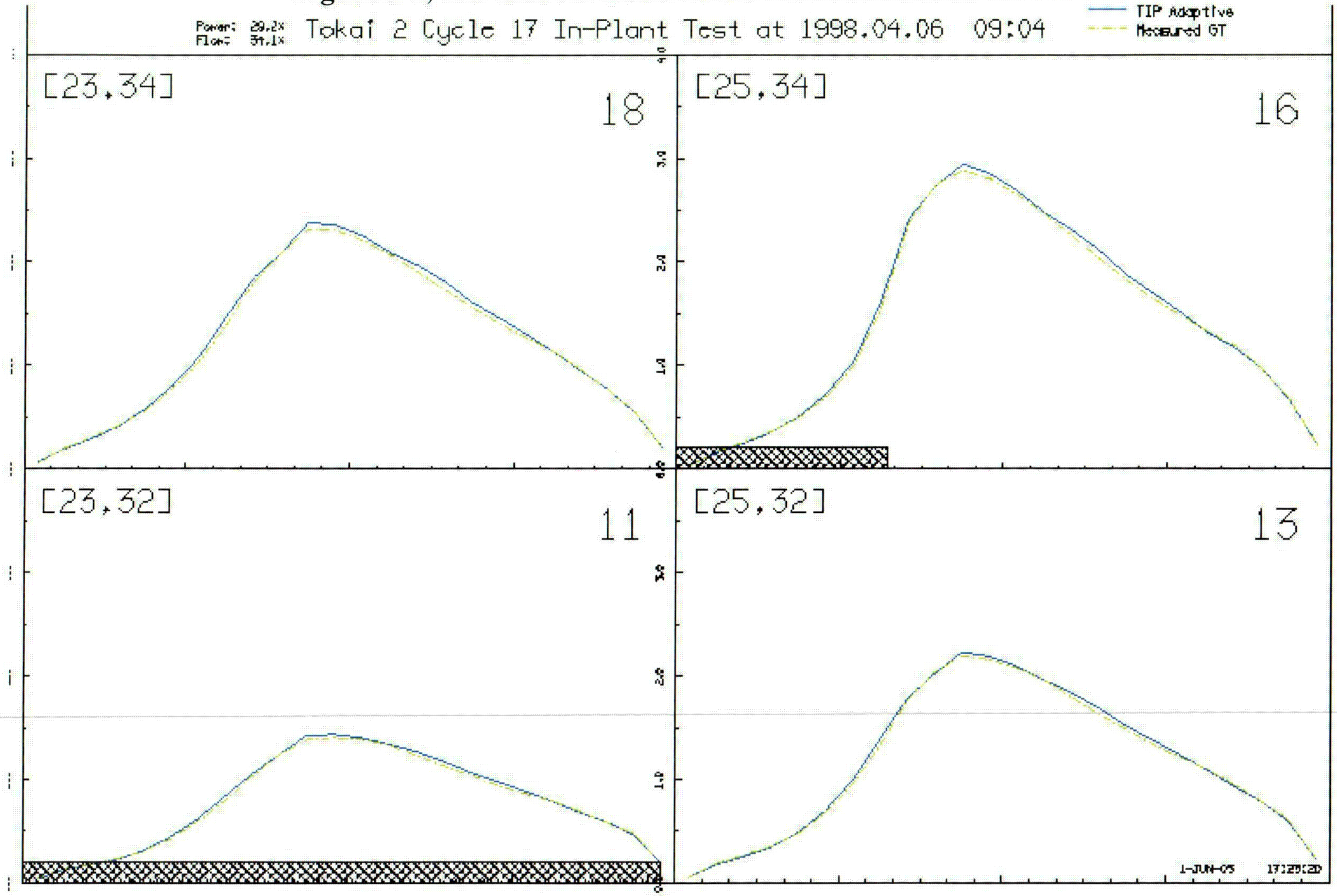
Table 8-6, TIP and GT Adaption Difference Summary for RSTK-02 (continued)

	Location:	(39,16)	(41,16)
RMS (rd)	Pwr.		
Mean	< 95%	2.8	3.6
Standard Dev.	< 95%	0.4	0.6
Standard Error	< 95%	0.2	0.4
Mean	≥ 95%	3.6	4.1
Standard Dev.	≥ 95%	0.3	0.6
Standard Error	≥ 95%	0.1	0.2
Mean	All	3.4	4.0
Standard Dev.	All	0.5	0.6
Standard Error	All	0.1	0.2
Peak to Peak (%)	Pwr.		
Mean	< 95%	0.9	1.8
Standard Dev.	< 95%	1.1	1.1
Standard Error	< 95%	0.6	0.6
Mean	≥ 95%	1.3	1.4
Standard Dev.	≥ 95%	1.0	0.8
Standard Error	≥ 95%	0.3	0.2
Mean	All	1.2	1.5
Standard Dev.	All	1.0	0.9
Standard Error	All	0.2	0.2
Bundle (%)	Pwr.		
Mean	< 95%	1.0	1.3
Standard Dev.	< 95%	0.7	0.5
Standard Error	< 95%	0.4	0.3
Mean	≥ 95%	1.1	1.4
Standard Dev.	≥ 95%	0.4	0.4
Standard Error	≥ 95%	0.1	0.1
Mean	All	1.1	1.4
Standard Dev.	All	0.5	0.4
Standard Error	All	0.1	0.1

Table 8-7, TIP and GT Adaption Difference Summary for RSTK-01 and RSTK-02

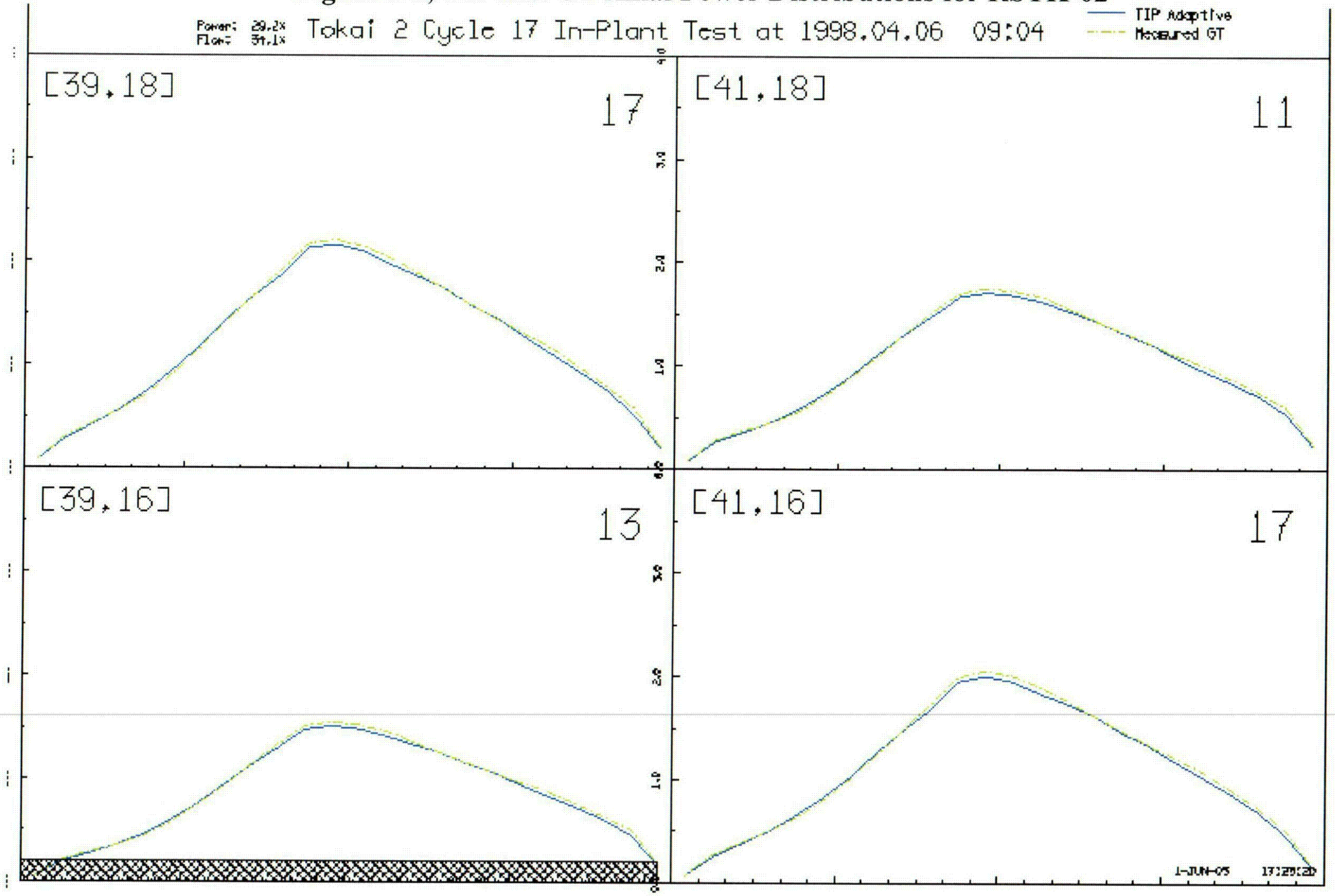
		All Nodes
RMS (rd)	Pwr.	
Mean	< 95%	3.2
Standard Dev.	< 95%	0.6
Standard Error	< 95%	0.1
Mean	≥ 95%	3.7
Standard Dev.	≥ 95%	0.6
Standard Error	≥ 95%	0.1
Mean	**All**	**3.6**
Standard Dev.	**All**	**0.6**
Standard Error	**All**	**0.1**
Peak to Peak (%)	Pwr.	
Mean	< 95%	0.3
Standard Dev.	< 95%	1.5
Standard Error	< 95%	0.3
Mean	≥ 95%	0.7
Standard Dev.	≥ 95%	1.3
Standard Error	≥ 95%	0.1
Mean	**All**	**0.6**
Standard Dev.	**All**	**1.4**
Standard Error	**All**	**0.1**
Bundle (%)	Pwr.	
Mean	< 95%	0.7
Standard Dev.	< 95%	1.1
Standard Error	< 95%	0.2
Mean	≥ 95%	1.2
Standard Dev.	≥ 95%	0.4
Standard Error	≥ 95%	0.0
Mean	**All**	**1.1**
Standard Dev.	**All**	**0.6**
Standard Error	**All**	**0.1**

Figure 8-1, TIP and GT Axial Power Distributions for RSTK-01



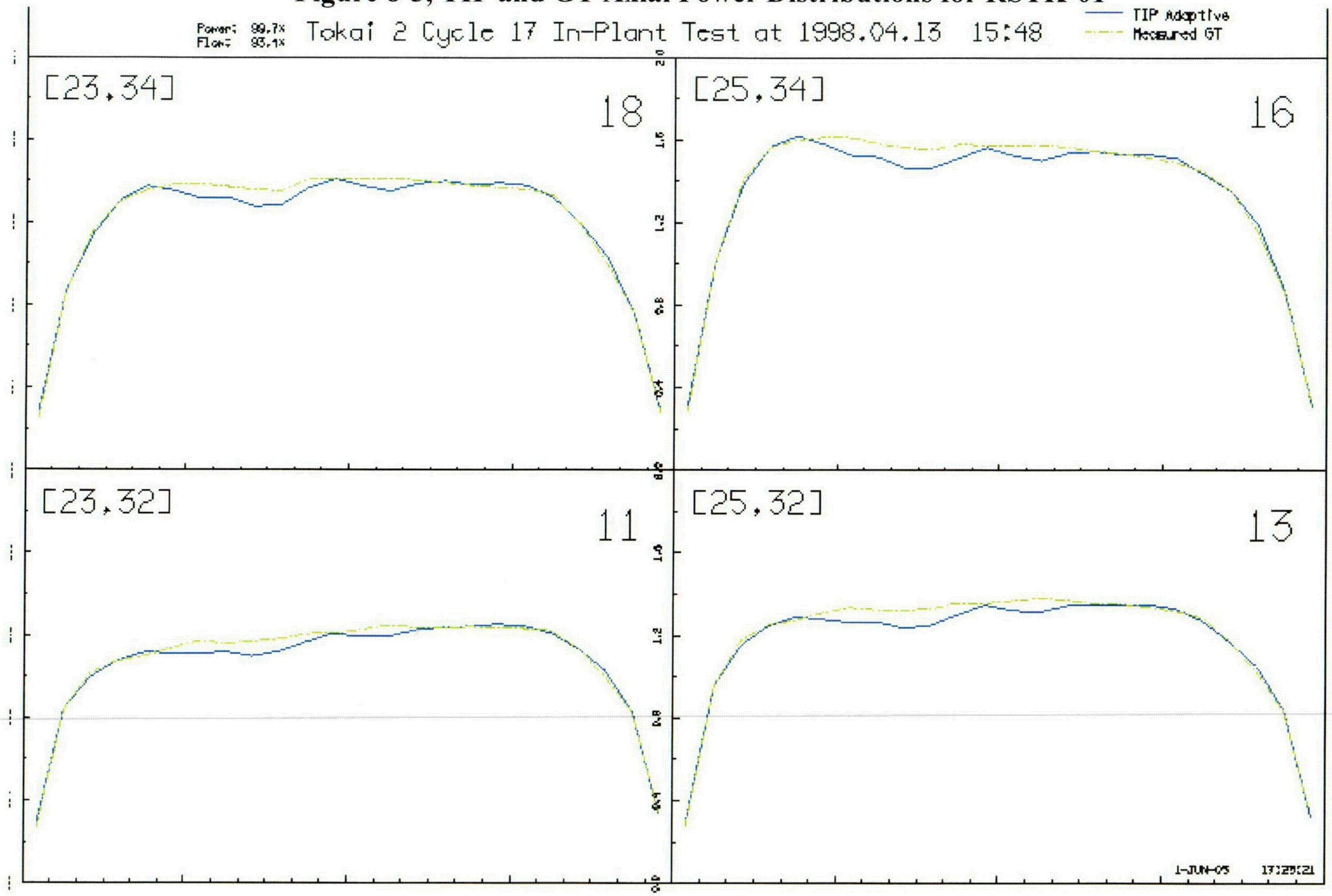
C32

Figure 8-2, TIP and GT Axial Power Distributions for RSTK-02



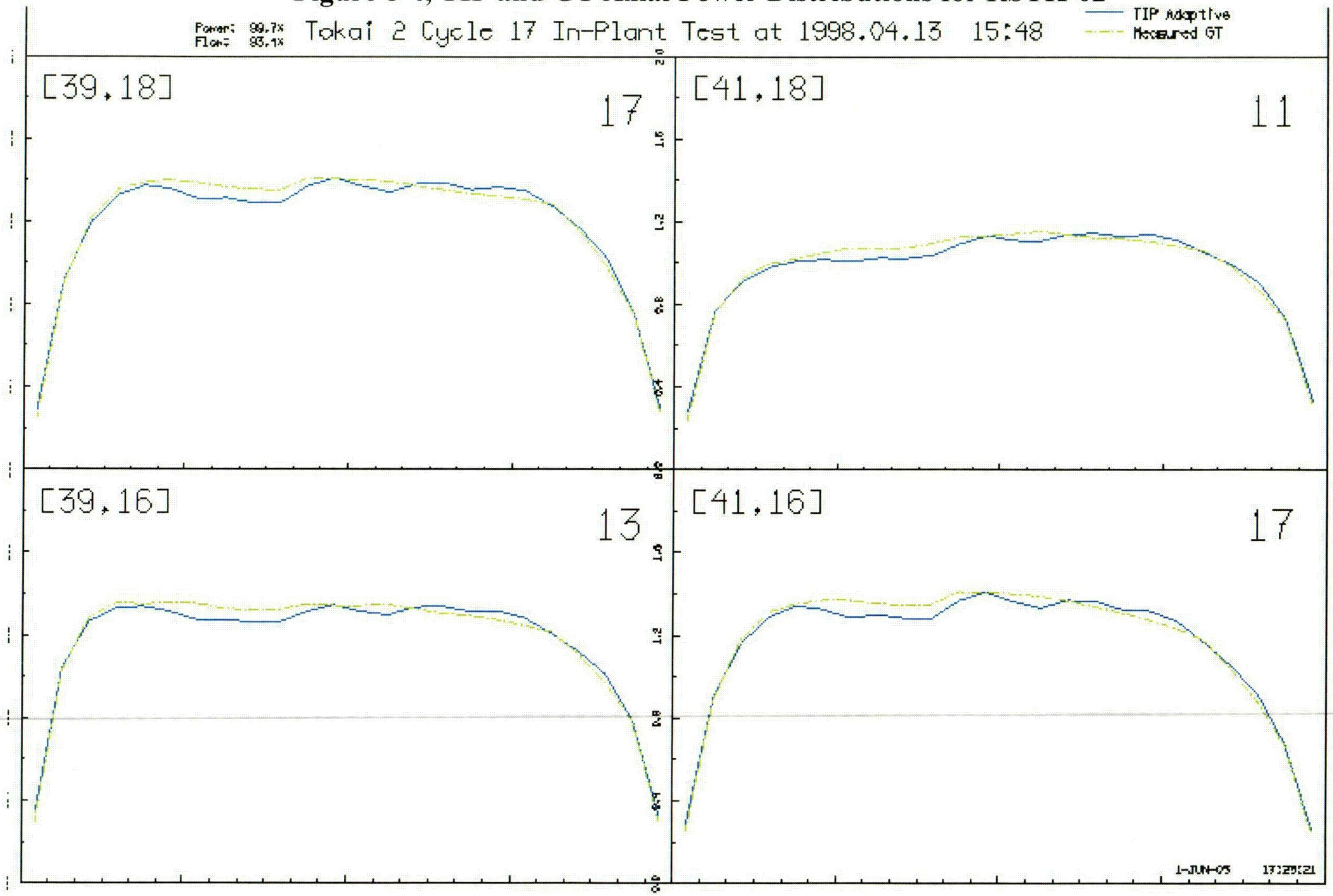
C33

Figure 8-3, TIP and GT Axial Power Distributions for RSTK-01



C34

Figure 8-4, TIP and GT Axial Power Distributions for RSTK-02



C35

8.2 Thermal Limit Comparison

[[

]]

Table 8-8, CPR from TIP and GT Adaption for RSTK-01

			Location (23,34)			Location (25,34)		
#	Date	Power %	TIP CPR	GT CPR	Diff. (%)	TIP CPR	GT CPR	Diff. (%)
1	19980406	29.2	3.880	3.967	2.3	3.286	3.341	1.7
2	19980406	55.8	2.336	2.327	-0.4	2.134	2.121	-0.6
3	19980407	83.3	1.925	1.897	-1.4	1.805	1.771	-1.9
18	19990401	92.3	1.959	1.939	-1.0	2.266	2.237	-1.3
	Mean	<95.0	--	--	-0.1	--	--	-0.5
	StDev	<95.0	--	--	1.4	--	--	1.4
	StErr	<95.0	--	--	0.8	--	--	0.8
4	19980413	99.7	1.856	1.827	-1.5	1.729	1.693	-2.1
5	19980423	99.6	1.863	1.842	-1.2	1.746	1.717	-1.7
6	19980430	99.6	1.860	1.842	-1.0	1.751	1.723	-1.6
7	19980518	99.4	1.865	1.842	-1.2	1.774	1.743	-1.8
8	19980525	99.5	1.837	1.816	-1.2	1.759	1.729	-1.7
9	19980605	99.5	1.834	1.813	-1.1	1.769	1.741	-1.6
10	19980616	99.5	1.828	1.802	-1.4	1.776	1.747	-1.6
11	19980723	99.8	1.816	1.793	-1.2	1.811	1.784	-1.5
12	19980831	99.8	1.806	1.779	-1.5	1.854	1.819	-1.9
13	19981006	99.7	1.771	1.743	-1.6	1.871	1.836	-1.9
14	19981112	99.5	1.777	1.760	-0.9	1.915	1.894	-1.1
15	19981217	99.5	1.817	1.787	-1.7	1.994	1.957	-1.9
16	19990121	99.4	1.718	1.694	-1.4	1.946	1.911	-1.8
17	19990225	98.7	1.802	1.783	-1.0	2.065	2.037	-1.3
	Mean	≥95.0	--	--	-1.3	--	--	-1.7
	StDev	≥95.0	--	--	0.2	--	--	0.2
	StErr	≥95.0	--	--	0.1	--	--	0.1
	Mean	All	--	--	-1.0	--	--	-1.4
	StDev	All	--	--	0.9	--	--	0.8
	StErr	All	--	--	0.2	--	--	0.2

Table 8-8, CPR from TIP and GT Adaption for RSTK-01 (continued)

			Location (23,32)			Location (25,32)		
#	Date	Power %	TIP CPR	GT CPR	Diff. (%)	TIP CPR	GT CPR	Diff. (%)
1	19980406	29.2	5.011	5.111	2.0	4.346	4.408	1.4
2	19980406	55.8	2.797	2.784	-0.4	2.604	2.582	-0.9
3	19980407	83.3	2.355	2.321	-1.4	2.166	2.123	-2.0
18	19990401	92.3	2.934	2.901	-1.1	2.669	2.627	-1.6
	Mean	<95.0	--	--	-0.2	--	--	-0.8
	StDev	<95.0	--	--	1.3	--	--	1.3
	StErr	<95.0	--	--	0.8	--	--	0.8
4	19980413	99.7	2.270	2.232	-1.7	2.047	1.999	-2.3
5	19980423	99.6	2.290	2.262	-1.2	2.068	2.030	-1.9
6	19980430	99.6	2.292	2.269	-1.0	2.071	2.035	-1.7
7	19980518	99.4	2.325	2.297	-1.2	2.100	2.061	-1.9
8	19980525	99.5	2.304	2.272	-1.4	2.084	2.042	-2.0
9	19980605	99.5	2.315	2.288	-1.2	2.094	2.056	-1.8
10	19980616	99.5	2.325	2.290	-1.5	2.103	2.063	-1.9
11	19980723	99.8	2.363	2.330	-1.4	2.134	2.095	-1.8
12	19980831	99.8	2.404	2.366	-1.6	2.174	2.127	-2.2
13	19981006	99.7	2.411	2.371	-1.6	2.192	2.145	-2.2
14	19981112	99.5	2.464	2.435	-1.2	2.236	2.202	-1.5
15	19981217	99.5	2.557	2.512	-1.8	2.316	2.268	-2.1
16	19990121	99.4	2.542	2.502	-1.6	2.308	2.258	-2.2
17	19990225	98.7	2.685	2.653	-1.2	2.439	2.398	-1.7
	Mean	≥95.0	--	--	-1.4	--	--	-1.9
	StDev	≥95.0	--	--	0.2	--	--	0.2
	StErr	≥95.0	--	--	0.1	--	--	0.1
	Mean	All	--	--	-1.1	--	--	-1.7
	StDev	All	--	--	0.8	--	--	0.8
	StErr	All	--	--	0.2	--	--	0.2

Table 8-9, CPR from TIP and GT Adaption for RSTK-02

			Location (39,18)			Location (41,18)		
#	Date	Power %	TIP CPR	GT CPR	Diff. (%)	TIP CPR	GT CPR	Diff. (%)
1	19980406	29.2	3.981	3.924	-1.4	5.148	5.063	-1.6
2	19980406	55.8	2.782	2.756	-0.9	3.714	3.670	-1.2
3	19980407	83.3	1.991	1.979	-0.6	2.718	2.697	-0.8
18	19990401	92.3	1.898	1.862	-1.9	2.665	2.616	-1.8
	Mean	<95.0	--	--	-1.2	--	--	-1.4
	StDev	<95.0	--	--	0.5	--	--	0.4
	StErr	<95.0	--	--	0.3	--	--	0.2
4	19980413	99.7	1.849	1.826	-1.2	2.517	2.485	-1.3
5	19980423	99.6	1.871	1.848	-1.2	2.545	2.513	-1.3
6	19980430	99.6	1.871	1.849	-1.1	2.548	2.517	-1.2
7	19980518	99.4	1.876	1.850	-1.4	2.557	2.519	-1.5
8	19980525	99.5	1.848	1.820	-1.5	2.512	2.471	-1.6
9	19980605	99.5	1.839	1.823	-0.9	2.503	2.479	-1.0
10	19980616	99.5	1.833	1.809	-1.3	2.496	2.465	-1.2
11	19980723	99.8	1.816	1.796	-1.1	2.475	2.444	-1.3
12	19980831	99.8	1.784	1.769	-0.9	2.442	2.420	-0.9
13	19981006	99.7	1.786	1.752	-1.9	2.461	2.412	-2.0
14	19981112	99.5	1.779	1.753	-1.5	2.445	2.409	-1.5
15	19981217	99.5	1.803	1.765	-2.1	2.475	2.424	-2.1
16	19990121	99.4	1.693	1.648	-2.7	2.413	2.348	-2.7
17	19990225	98.7	1.756	1.722	-1.9	2.481	2.437	-1.8
	Mean	≥95.0	--	--	-1.5	--	--	-1.5
	StDev	≥95.0	--	--	0.5	--	--	0.5
	StErr	≥95.0	--	--	0.1	--	--	0.1
	Mean	All	--	--	-1.4	--	--	-1.5
	StDev	All	--	--	0.5	--	--	0.5
	StErr	All	--	--	0.1	--	--	0.1

Table 8-9, CPR from TIP and GT Adaption for RSTK-02 (continued)

			Location (39,16)			Location (41,16)		
#	Date	Power %	TIP CPR	GT CPR	Diff. (%)	TIP CPR	GT CPR	Diff. (%)
1	19980406	29.2	4.709	4.627	-1.7	4.337	4.258	-1.8
2	19980406	55.8	3.221	3.194	-0.8	3.030	2.989	-1.3
3	19980407	83.3	2.117	2.106	-0.5	2.109	2.089	-0.9
18	19990401	92.3	2.463	2.417	-1.9	1.888	1.848	-2.1
	Mean	<95.0	--	--	-1.2	--	--	-1.6
	StDev	<95.0	--	--	0.6	--	--	0.4
	StErr	<95.0	--	--	0.3	--	--	0.3
4	19980413	99.7	2.042	2.018	-1.2	1.911	1.884	-1.5
5	19980423	99.6	2.072	2.045	-1.3	1.934	1.904	-1.6
6	19980430	99.6	2.074	2.050	-1.2	1.933	1.905	-1.4
7	19980518	99.4	2.097	2.067	-1.4	1.932	1.900	-1.7
8	19980525	99.5	1.986	1.956	-1.5	1.901	1.866	-1.9
9	19980605	99.5	1.985	1.968	-0.9	1.882	1.860	-1.1
10	19980616	99.5	1.992	1.966	-1.3	1.870	1.844	-1.4
11	19980723	99.8	1.976	1.954	-1.1	1.840	1.813	-1.5
12	19980831	99.8	1.983	1.966	-0.8	1.791	1.769	-1.2
13	19981006	99.7	2.020	1.985	-1.8	1.788	1.751	-2.1
14	19981112	99.5	2.047	2.020	-1.3	1.762	1.730	-1.8
15	19981217	99.5	2.103	2.061	-2.0	1.766	1.724	-2.4
16	19990121	99.4	2.183	2.131	-2.4	1.717	1.668	-2.9
17	19990225	98.7	2.274	2.234	-1.8	1.761	1.727	-1.9
	Mean	≥95.0	--	--	-1.4	--	--	-1.7
	StDev	≥95.0	--	--	0.4	--	--	0.5
	StErr	≥95.0	--	--	0.1	--	--	0.1
	Mean	All	--	--	-1.4	--	--	-1.7
	StDev	All	--	--	0.5	--	--	0.5
	StErr	All	--	--	0.1	--	--	0.1

Table 8-10, LHGR from TIP and GT Adaption for RSTK-01

			Location (23,34)			Location (25,34)		
#	Date	Power %	TIP LHGR	GT LHGR	Diff. (%)	TIP LHGR	GT LHGR	Diff. (%)
1	19980406	29.2	5.080	4.940	-2.8	5.370	5.270	-2.0
2	19980406	55.8	6.730	6.690	-0.7	6.220	6.190	-0.5
3	19980407	83.3	9.010	8.930	-0.9	8.930	8.940	0.0
18	19990401	92.3	9.550	9.530	-0.2	8.130	8.120	-0.1
	Mean	<95.0	--	--	-1.1	--	--	-0.6
	StDev	<95.0	--	--	1.0	--	--	0.8
	StErr	<95.0	--	--	0.6	--	--	0.5
4	19980413	99.7	10.110	10.150	0.4	9.740	9.710	-0.3
5	19980423	99.6	10.280	10.180	-1.0	9.810	9.770	-0.4
6	19980430	99.6	10.330	10.260	-0.7	9.840	9.840	0.0
7	19980518	99.4	10.390	10.320	-0.7	9.830	9.830	0.0
8	19980525	99.5	10.710	10.620	-0.8	9.990	10.050	0.6
9	19980605	99.5	10.750	10.660	-0.9	10.060	10.060	-0.1
10	19980616	99.5	10.790	10.750	-0.4	10.110	10.130	0.2
11	19980723	99.8	11.070	11.000	-0.6	10.280	10.230	-0.5
12	19980831	99.8	11.270	11.030	-2.1	10.300	10.110	-1.8
13	19981006	99.7	10.950	10.900	-0.5	9.690	9.700	0.1
14	19981112	99.5	10.800	10.810	0.1	9.580	9.520	-0.7
15	19981217	99.5	10.630	10.740	1.0	9.330	9.370	0.4
16	19990121	99.4	10.250	10.350	0.9	8.670	8.900	2.7
17	19990225	98.7	10.100	10.200	1.0	8.610	8.740	1.5
	Mean	≥95.0	--	--	-0.3	--	--	0.1
	StDev	≥95.0	--	--	0.9	--	--	1.0
	StErr	≥95.0	--	--	0.2	--	--	0.3
	Mean	All	--	--	-0.5	--	--	0.0
	StDev	All	--	--	0.9	--	--	1.0
	StErr	All	--	--	0.2	--	--	0.2

Table 8-10, LHGR from TIP and GT Adaption for RSTK-01 (continued)

			Location (23,32)			Location (25,32)		
#	Date	Power %	TIP LHGR	GT LHGR	Diff. (%)	TIP LHGR	GT LHGR	Diff. (%)
1	19980406	29.2	3.290	3.220	-2.2	3.930	3.870	-1.7
2	19980406	55.8	5.090	5.080	-0.2	5.280	5.260	-0.4
3	19980407	83.3	6.520	6.510	-0.2	7.310	7.330	0.3
18	19990401	92.3	6.640	6.530	-1.7	7.060	7.030	-0.3
	Mean	<95.0	--	--	-1.1	--	--	-0.5
	StDev	<95.0	--	--	0.9	--	--	0.7
	StErr	<95.0	--	--	0.5	--	--	0.4
4	19980413	99.7	7.550	7.460	-1.2	8.130	8.290	2.0
5	19980423	99.6	7.640	7.540	-1.3	8.340	8.330	-0.1
6	19980430	99.6	7.780	7.590	-2.4	8.390	8.400	0.1
7	19980518	99.4	7.740	7.630	-1.5	8.390	8.380	0.0
8	19980525	99.5	7.930	7.790	-1.7	8.490	8.580	1.0
9	19980605	99.5	7.940	7.810	-1.7	8.550	8.580	0.3
10	19980616	99.5	7.970	7.840	-1.5	8.610	8.640	0.4
11	19980723	99.8	8.140	8.000	-1.7	8.780	8.760	-0.2
12	19980831	99.8	8.250	8.090	-1.9	8.840	8.700	-1.5
13	19981006	99.7	7.750	7.730	-0.2	8.330	8.360	0.3
14	19981112	99.5	7.740	7.610	-1.7	8.290	8.270	-0.2
15	19981217	99.5	7.590	7.490	-1.3	8.130	8.160	0.4
16	19990121	99.4	6.980	7.060	1.2	7.490	7.700	2.8
17	19990225	98.7	7.000	6.970	-0.4	7.460	7.580	1.5
	Mean	≥95.0	--	--	-1.2	--	--	0.5
	StDev	≥95.0	--	--	0.9	--	--	1.0
	StErr	≥95.0	--	--	0.2	--	--	0.3
	Mean	All	--	--	-1.2	--	--	0.2
	StDev	All	--	--	0.9	--	--	1.1
	StErr	All	--	--	0.2	--	--	0.3

Table 8-11, LHGR from TIP and GT Adaption for RSTK-02

			Location (39,18)			Location (41,18)		
#	Date	Power %	TIP LHGR	GT LHGR	Diff. (%)	TIP LHGR	GT LHGR	Diff. (%)
1	19980406	29.2	4.580	4.680	2.1	3.020	3.090	2.2
2	19980406	55.8	5.020	5.170	3.1	3.390	3.470	2.5
3	19980407	83.3	9.380	9.460	0.9	6.310	6.360	0.8
18	19990401	92.3	9.330	9.310	-0.2	6.610	6.670	0.9
	Mean	<95.0	--	--	1.5	--	--	1.6
	StDev	<95.0	--	--	1.2	--	--	0.8
	StErr	<95.0	--	--	0.7	--	--	0.4
4	19980413	99.7	10.090	10.100	0.1	6.870	6.920	0.6
5	19980423	99.6	9.950	10.110	1.6	6.960	6.960	-0.1
6	19980430	99.6	10.110	10.140	0.3	6.980	7.000	0.2
7	19980518	99.4	10.140	10.140	0.0	7.060	7.040	-0.4
8	19980525	99.5	10.890	11.130	2.2	7.450	7.550	1.4
9	19980605	99.5	11.080	11.050	-0.3	7.440	7.530	1.2
10	19980616	99.5	10.990	11.090	1.0	7.480	7.580	1.3
11	19980723	99.8	11.460	11.560	0.8	7.810	7.960	1.8
12	19980831	99.8	11.420	11.460	0.4	7.920	7.980	0.8
13	19981006	99.7	11.340	11.580	2.1	7.790	8.010	2.9
14	19981112	99.5	11.310	11.490	1.7	7.810	7.950	1.9
15	19981217	99.5	11.110	11.360	2.3	7.690	7.930	3.1
16	19990121	99.4	10.350	10.470	1.1	7.180	7.400	3.1
17	19990225	98.7	10.280	10.340	0.5	7.170	7.340	2.3
	Mean	≥95.0	--	--	1.0	--	--	1.4
	StDev	≥95.0	--	--	0.8	--	--	1.1
	StErr	≥95.0	--	--	0.2	--	--	0.3
	Mean	All	--	--	1.1	--	--	1.5
	StDev	All	--	--	1.0	--	--	1.0
	StErr	All	--	--	0.2	--	--	0.2

Table 8-11, LHGR from TIP and GT Adaption for RSTK-02 (continued)

			Location (39,16)			Location (41,16)		
#	Date	Power %	TIP LHGR	GT LHGR	Diff. (%)	TIP LHGR	GT LHGR	Diff. (%)
1	19980406	29.2	3.490	3.570	2.3	4.250	4.350	2.4
2	19980406	55.8	4.350	4.340	-0.4	4.770	4.930	3.4
3	19980407	83.3	8.090	8.190	1.2	9.110	9.220	1.2
18	19990401	92.3	7.110	7.250	2.0	9.490	9.470	-0.2
	Mean	<95.0	--	--	1.3	--	--	1.7
	StDev	<95.0	--	--	1.0	--	--	1.3
	StErr	<95.0	--	--	0.6	--	--	0.8
4	19980413	99.7	8.200	8.330	1.5	10.080	10.120	0.4
5	19980423	99.6	8.110	8.140	0.3	9.920	10.120	2.0
6	19980430	99.6	8.190	8.190	0.0	10.090	10.150	0.6
7	19980518	99.4	8.240	8.200	-0.5	10.140	10.180	0.4
8	19980525	99.5	8.830	9.080	2.8	10.880	11.170	2.7
9	19980605	99.5	8.980	9.000	0.2	11.120	11.130	0.1
10	19980616	99.5	8.870	8.990	1.4	11.030	11.170	1.2
11	19980723	99.8	9.310	9.420	1.1	11.590	11.720	1.1
12	19980831	99.8	9.160	9.270	1.2	11.600	11.700	0.9
13	19981006	99.7	9.230	9.450	2.3	11.510	11.770	2.3
14	19981112	99.5	9.080	9.270	2.0	11.530	11.730	1.7
15	19981217	99.5	8.850	9.110	3.0	11.380	11.640	2.2
16	19990121	99.4	8.210	8.590	4.7	10.290	10.480	1.9
17	19990225	98.7	7.880	8.210	4.2	10.370	10.420	0.4
	Mean	≥95.0	--	--	1.7	--	--	1.3
	StDev	≥95.0	--	--	1.5	--	--	0.8
	StErr	≥95.0	--	--	0.4	--	--	0.2
	Mean	All	--	--	1.6	--	--	1.4
	StDev	All	--	--	1.4	--	--	1.0
	StErr	All	--	--	0.3	--	--	0.2

Table 8-12, TIP and GT Adaption Thermal Limit Difference Summary for RSTK-01

	Location:	(23,34)	(25,34)
CPR (%)	Pwr.		
Mean	< 95%	-0.1	-0.5
Standard Dev.	< 95%	1.4	1.4
Standard Error	< 95%	0.8	0.8
Mean	≥ 95%	-1.3	-1.7
Standard Dev.	≥ 95%	0.2	0.2
Standard Error	≥ 95%	0.1	0.1
Mean	All	**-1.0**	**-1.4**
Standard Dev.	All	**0.9**	**0.8**
Standard Error	All	**0.2**	**0.2**
LHGR (%)	Pwr.		
Mean	< 95%	-1.1	-0.6
Standard Dev.	< 95%	1.0	0.8
Standard Error	< 95%	0.6	0.5
Mean	≥ 95%	-0.3	0.1
Standard Dev.	≥ 95%	0.9	1.0
Standard Error	≥ 95%	0.2	0.3
Mean	All	**-0.5**	**0.0**
Standard Dev.	All	**0.9**	**1.0**
Standard Error	All	**0.2**	**0.2**

Table 8-12, TIP and GT Adaption Thermal Limit Difference Summary for RSTK-01 (continued)

Location:		(23,32)	(25,32)
CPR (%)	Pwr.		
Mean	< 95%	-0.2	-0.8
Standard Dev.	< 95%	1.3	1.3
Standard Error	< 95%	0.8	0.8
Mean	≥ 95%	-1.4	-1.9
Standard Dev.	≥ 95%	0.2	0.2
Standard Error	≥ 95%	0.1	0.1
Mean	**All**	**-1.1**	**-1.7**
Standard Dev.	**All**	**0.8**	**0.8**
Standard Error	**All**	**0.2**	**0.2**
LHGR (%)	Pwr.		
Mean	< 95%	-1.1	-0.5
Standard Dev.	< 95%	0.9	0.7
Standard Error	< 95%	0.5	0.4
Mean	≥ 95%	-1.2	0.5
Standard Dev.	≥ 95%	0.9	1.0
Standard Error	≥ 95%	0.2	0.3
Mean	**All**	**-1.2**	**0.2**
Standard Dev.	**All**	**0.9**	**1.1**
Standard Error	**All**	**0.2**	**0.3**

Table 8-13, TIP and GT Adaption Thermal Limit Difference Summary for RSTK-02

	Location:	(39,18)	(41,18)
CPR (%)	Pwr.		
Mean	< 95%	-1.2	-1.4
Standard Dev.	< 95%	0.5	0.4
Standard Error	< 95%	0.3	0.2
Mean	≥ 95%	-1.5	-1.5
Standard Dev.	≥ 95%	0.5	0.5
Standard Error	≥ 95%	0.1	0.1
Mean	**All**	**-1.4**	**-1.5**
Standard Dev.	**All**	**0.5**	**0.5**
Standard Error	**All**	**0.1**	**0.1**
LHGR (%)	Pwr.		
Mean	< 95%	1.5	1.6
Standard Dev.	< 95%	1.2	0.8
Standard Error	< 95%	0.7	0.4
Mean	≥ 95%	1.0	1.4
Standard Dev.	≥ 95%	0.8	1.1
Standard Error	≥ 95%	0.2	0.3
Mean	**All**	**1.1**	**1.5**
Standard Dev.	**All**	**1.0**	**1.0**
Standard Error	**All**	**0.2**	**0.2**

Table 8-13, TIP and GT Adaption Thermal Limit Difference Summary for RSTK-02 (continued)

	Location:	(39,16)	(41,16)
CPR (%)	Pwr.		
Mean	< 95%	-1.2	-1.6
Standard Dev.	< 95%	0.6	0.4
Standard Error	< 95%	0.3	0.3
Mean	≥ 95%	-1.4	-1.7
Standard Dev.	≥ 95%	0.4	0.5
Standard Error	≥ 95%	0.1	0.1
Mean	**All**	**-1.4**	**-1.7**
Standard Dev.	**All**	**0.5**	**0.5**
Standard Error	**All**	**0.1**	**0.1**
LHGR (%)	Pwr.		
Mean	< 95%	1.3	1.7
Standard Dev.	< 95%	1.0	1.3
Standard Error	< 95%	0.6	0.8
Mean	≥ 95%	1.7	1.3
Standard Dev.	≥ 95%	1.5	0.8
Standard Error	≥ 95%	0.4	0.2
Mean	**All**	**1.6**	**1.4**
Standard Dev.	**All**	**1.4**	**1.0**
Standard Error	**All**	**0.3**	**0.2**

Table 8-14, TIP and GT Adaption Thermal Limit Difference Summary for RSTK-01 and RSTK-02

		All Nodes
CPR (%)	Pwr.	
Mean	< 95%	-0.9
Standard Dev.	< 95%	1.1
Standard Error	< 95%	0.2
Mean	≥ 95%	-1.6
Standard Dev.	≥ 95%	0.4
Standard Error	≥ 95%	0.0
Mean	All	**-1.4***
Standard Dev.	All	**0.7**
Standard Error	All	**0.1**
LHGR (%)	Pwr.	
Mean	< 95%	0.3
Standard Dev.	< 95%	1.6
Standard Error	< 95%	0.3
Mean	≥ 95%	0.6
Standard Dev.	≥ 95%	1.4
Standard Error	≥ 95%	0.1
Mean	All	**0.5**
Standard Dev.	All	**1.4**
Standard Error	All	**0.1**

* In terms of delta CPR, this value is –0.030 with a standard deviation of 0.022 and a standard error of 0.002.

9. UNCERTAINTY ANALYSIS

[[

]]

9.1 GT Sensor Accuracy

[[

]]

Table 9-1, SRS Requirements

	Description	Required Value	Actual Value (as-built)	Meets Req.?
1	Expected Gamma Heating Rate	2.4 w/g	test to 4.3w/g	√
2	Thermocouple Type	K	K	√
3	GT Sensitivity (beginning-of-life) at 286°C	1.5 mV-g/W ±20%	1.36-1.50 mV-g/W	√
4	GT Sensitivity (beginning-of-life) at 20°C	2.0 mV-g/W ±20%	1.99 mV-g/W ±5%	√
5	GT Heater Heat Rate (286°C, 3A)	1.0 W/g ± 20%	0.97-0.99 W/g @ 25°C	√
6	Minimum Heater Current Capability	3.0 A	3.0 A	√
7	Minimum GT Response to Rated Heater Current	1.0 mV	1.7-2.0 mV	√
8	Detector Thermal Response Time	< 20 s	18-19 s	√
9	Accuracy of Heater Wire Linear Resistance (as measured for an individual GT sensor)	± 1.0% Ω/cm (1σ)	± 0.48%	√
10	Accuracy of Sensor Linear Mass (as measured for an individual GT sensor)	± 1.0% g/cm (1σ)	± 0.28%	√
11	Minimum Cooling	no boiling when LPRMs in use		NT
12	Thermocouple (TC) resistance	< 1.5 kΩ	730-990 Ω	√
13	Minimum TC Insulation Resistance lead-to-sheath (20°C)	$1x10^9$ Ω	$2\text{-}5x10^9$ Ω	√
14	Minimum Heater Wire Insulation Resistance (20°C)	$1x10^9$ Ω	$2x10^{11}$ Ω	√

[[

]]

Table 9-2, GT Sensor Accuracy Criteria

	Description	Target Value	Actual Value (test result)	Meets Req.?
1	GT Accuracy (with respect to n-TIPs)[6]	< 6% RMS	3.6% RMS	√
2	GT Linearity (with respect to LPRMs)	± 1 meter unit	± 1 meter unit[7]	√
3	GT Range	5% to 100% Local Power	<2% to 107% Local Power	√

9.2 GT Calibration Accuracy

[[

[4] A "meter unit" is 1% of the average peak APLHGR (highest of the eight values surrounding an LPRM) divided by LIMHGR (ex., 12.0 KW/ft) and the fraction of rated power. The value of a meter unit changes slightly with each monitoring case. As a practical matter, the value of one meter unit for the last monitoring case for Tokai 2 at the end of cycle 17 was determined by dividing the core average power density by the average LPRM reading in meter units: 46.02 KW/l / 51.13 meter units = 0.900 KW/l.

[5] 59.3 meter units * (46.02 KW/l / 51.13 meter units) = 53.4 KW/l

[6] Includes neutron and gamma detector correlation errors.

[7] When delayed gamma compensation is used.

]]

Table 9-3, GT Uncertainty Analysis

Parameter	Nominal Value	Accuracy	σ	Multiplier	Contribution to σ_w/w
U	1.82mV	0.5% of FSR	0.83%*	0.966	0.80%
ΔU	1.28mV	0.22% of FSR	0.51%	1.024	0.53%
I	3.0A	0.7% of FSR	0.35%	2.0	0.70%
r_h	0.165Ω/cm	±1.0%(1σ)	1.0%	1.0	1.00%
m_c	1.52g/cm	±1.0%(1σ)	1.0%	1.0	1.00%
r_h/m_c	0.1086Ω/g			N/A	
S_o	1.45mVg/W			N/A	
α	-0.0196	±5%(1σ)	5.0%	0.057	0.29%
w	1.3W/g			N/A	
Total					1.9%

9.2.1 <u>Interval Between Calibrations</u>

[[

* $\sigma = \frac{1}{2}\ 0.5\%\ 6mV/3.46mV$

]]

Table 9-4, Calibration Accuracy Criteria

	Description	Target Value	Actual Value (test result)	Meets Req.?
1	Sensitivity Projection Error	< 1% RMS	0.6% RMS	√

9.3 GT Adaptive Core Monitoring Accuracy

[[

]]

Table 9-5, GT Core Monitoring Accuracy Criteria (with respect to n-TIP)

	Description	Target Value	Actual Value (test result)	Meets Req.?
1	GT Nodal Power Uncertainty (σ±2se)	< 6%	3.6%±0.2%⇒3.8%	√
2	GT Bundle Power Uncertainty (σ±2se)	< 4%	1.1%±0.2%⇒1.3%	√
3	GT CPR Bias ± 2σ	< 2%	-1.4%±1.4%⇒0.0%	√
4	GT LHGR Bias ± 2σ	< 5%	0.5%±2.8%⇒-2.3%	√

[[

]]

9.3.1 GT Nodal Power Uncertainty

[[

]]

[[

]]

[[

]]

Table 9-6, Core Monitoring Nodal Power Uncertainty with Simulated GTs (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Simulated Value ±2se	Additional Unc.
1	Simulated GTs	43	9	2.49%±0.02%	--
2	Simulated GTs	43	7	2.95%±0.02%	1.58%
3	Simulated GTs	43	4	3.56%±0.02%	2.54%

[[

]]

Table 9-7, Estimated Core Monitoring Nodal Power Uncertainty (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Target Value	Actual/*Estimated Value* ±2se	Meets Req.?
1	Measured GTs	2	9	< 6%	3.6%±0.2%⇒3.8%	√
2	Simulated GTs	43	7	< 6%	*3.9%±0.2%⇒4.1%*	√
3	Simulated GTs	43	4	< 6%	*4.4%±0.2%⇒4.6%*	√

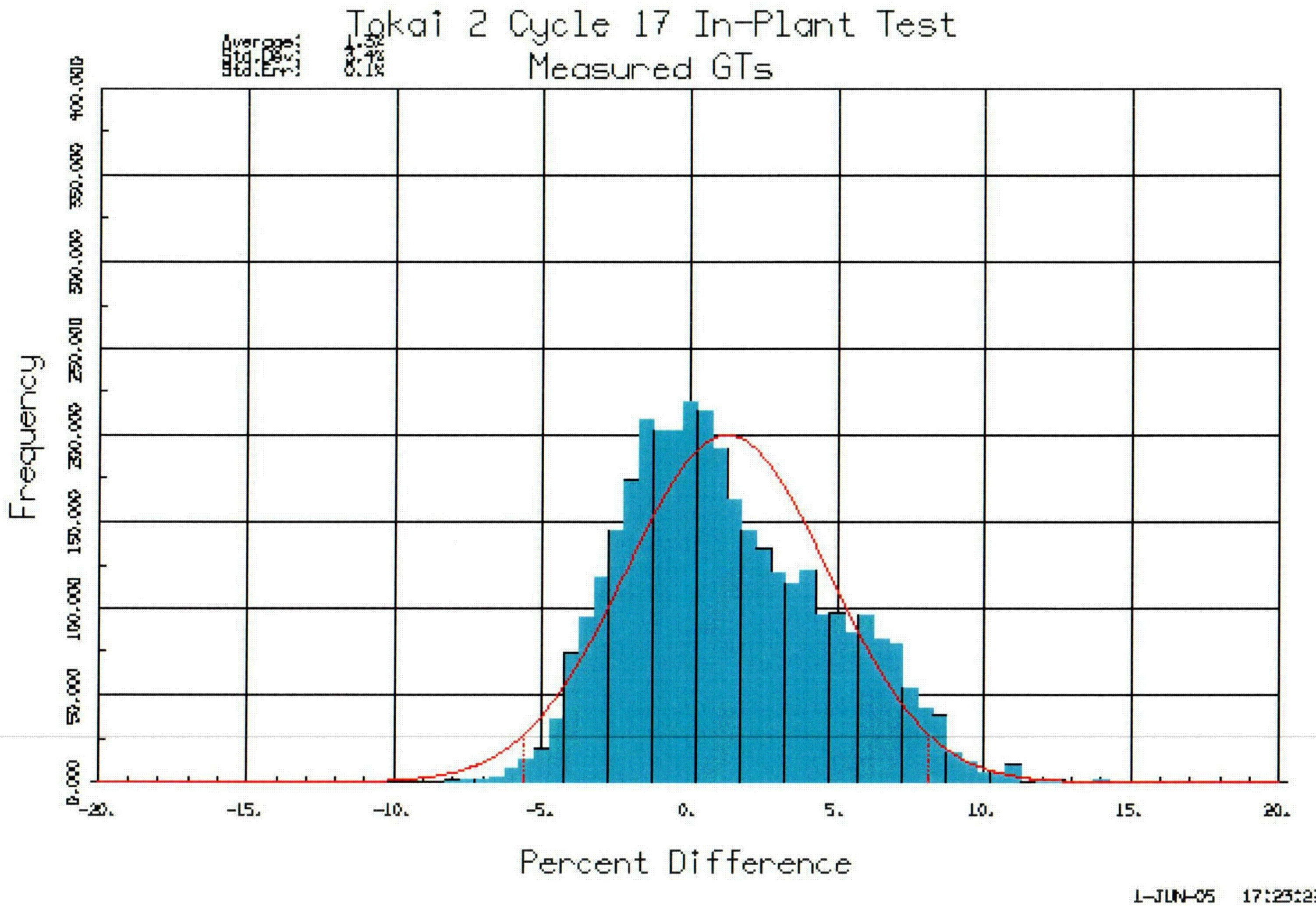
[[

]]

Table 9-8, Core Monitoring Bundle Power Uncertainty with Simulated GTs (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Simulated Value ±2se	Additional Unc.
1	Simulated GTs	43	9	1.50%±0.01%	--
2	Simulated GTs	43	7	1.02%±0.01%	~0.0%
3	Simulated GTs	43	4	1.17%±0.01%	~0.0%

Figure 9-1, Nodal Power Difference Histogram



C36

9.3.2 GT CPR Bias

[[

]]

Table 9-9, Core Monitoring CPR Bias with Simulated GTs (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Simulated Value ±2σ	Additional Diff. ±2σ
1	Simulated GTs	43	9	0.07%±3.26%	--
2	Simulated GTs	43	7	0.02%±2.20%	-0.05%±0%
3	Simulated GTs	43	4	0.08%±2.52%	0.01%±0%

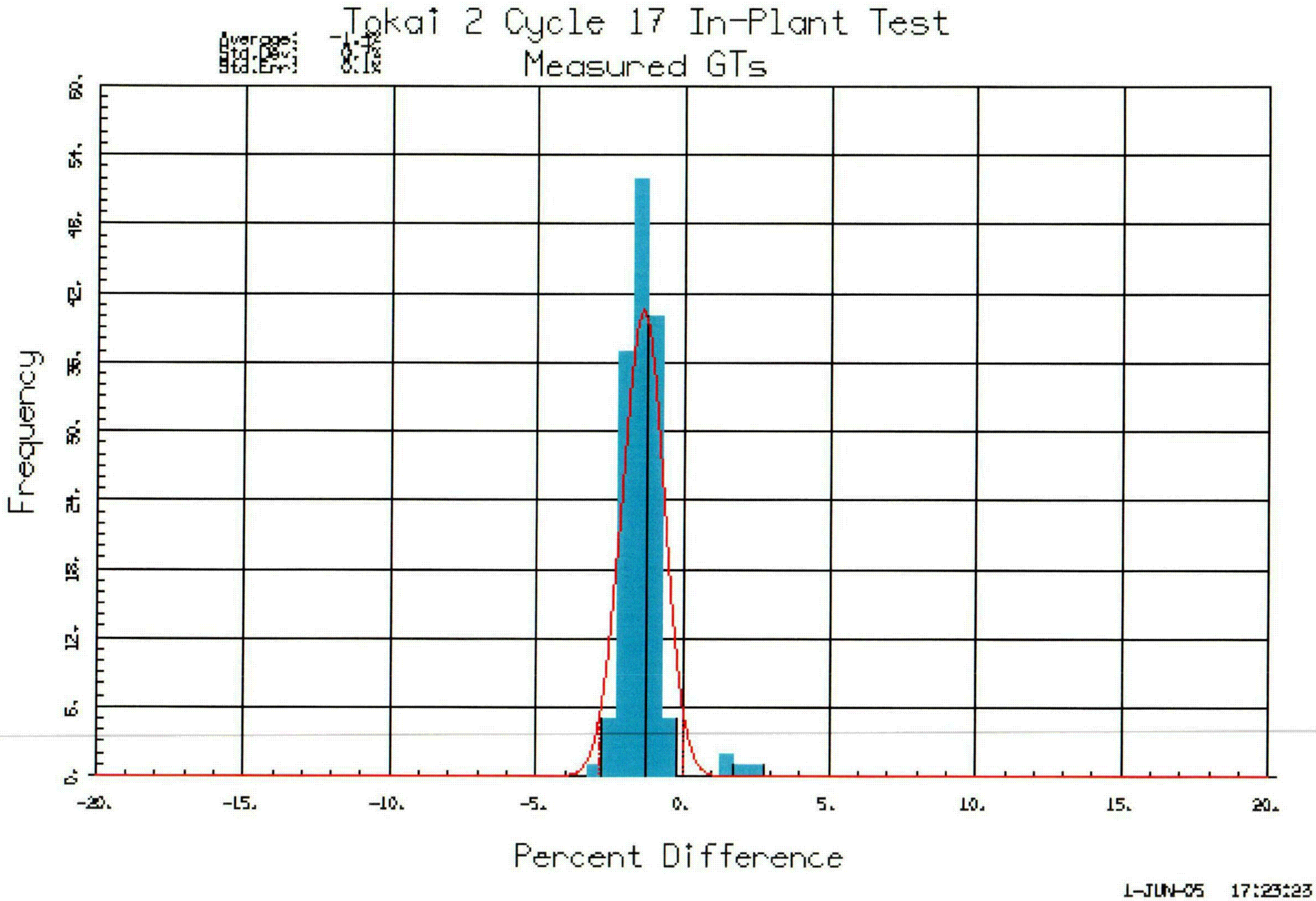
[[

]]

Table 9-10, Estimated Core Monitoring CPR Bias (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Target Value	Actual/*Estimated Value* ±2σ	Meets Req.?
1	Measured GTs	2	9	< 2%	-1.4%±1.4%⇒0.0%	√
2	Simulated GTs	43	7	< 2%	*-1.4%±1.4%⇒0.0%*	√
3	Simulated GTs	43	4	< 2%	*-1.4%±1.4%⇒0.0%*	√

Figure 9-2, CPR Difference Histogram



C37

9.3.3 GT LHGR Bias

[[

]]

Table 9-11, Core Monitoring LHGR Bias with Simulated GTs (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Simulated Value ±2σ	Additional Diff. ±2σ
1	Simulated GTs	43	9	-0.29%±4.04%	--
2	Simulated GTs	43	7	-0.53%±3.22%	-0.24%±0.00%
3	Simulated GTs	43	4	-0.72%±4.08%	-0.43%±0.57%

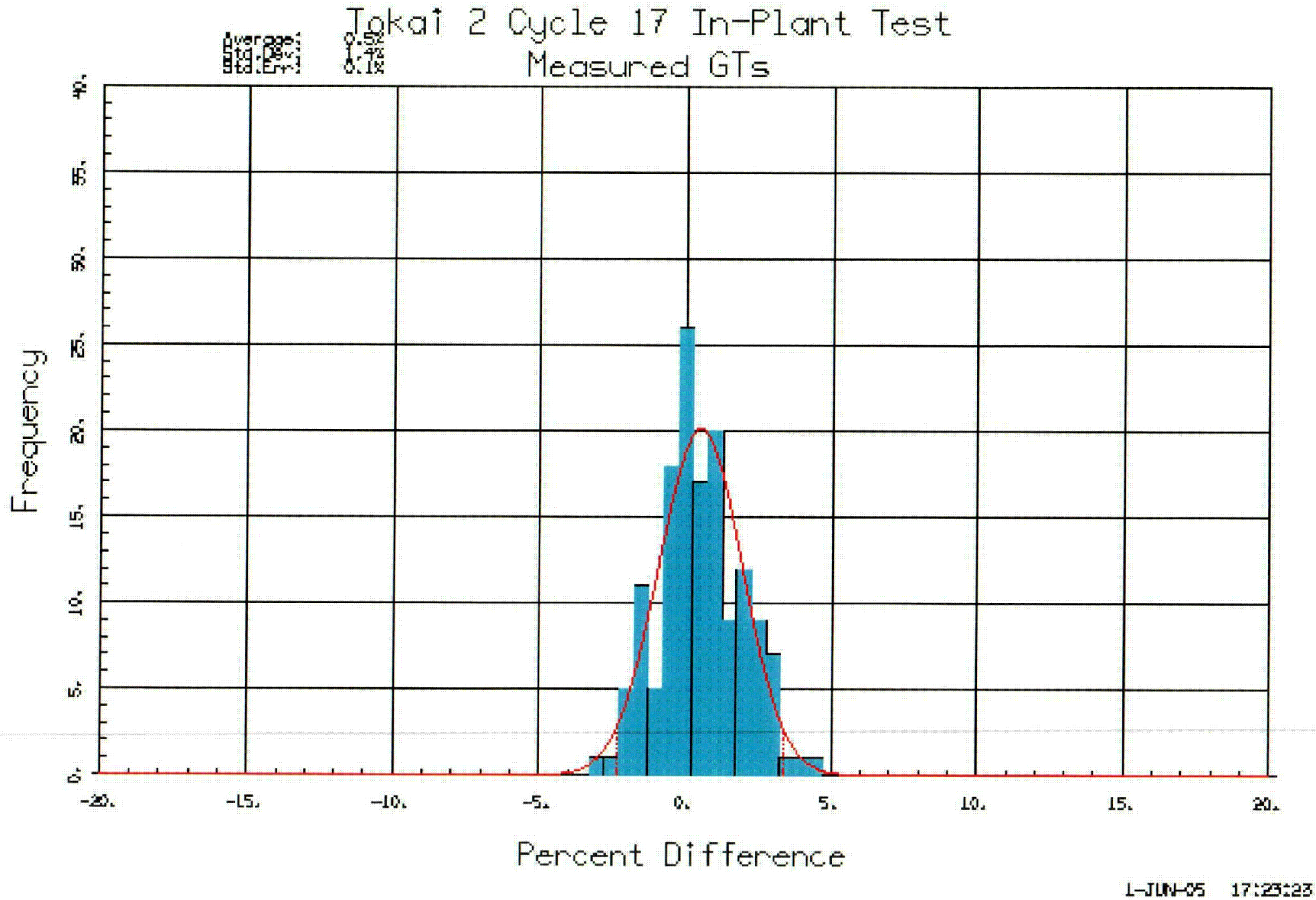
[[

]]

Table 9-12, Estimated Core Monitoring LHGR Bias (with respect to n-TIP)

	Description	# of GT Assemblies	# of GTs	Target Value	Actual/*Estimated Value* ±2σ	Meets Req.?
1	Measured GTs	2	9	< 5%	0.5%±2.8%	√
2	Simulated GTs	43	7	< 5%	*0.3%±2.8%*	√
3	Simulated GTs	43	4	< 5%	*0.1%±2.9%*	√

Figure 9-3, LHGR Difference Histogram



C38

9.4 Estimated Bundle Power Uncertainty

[[

]]

Table 9-13, Expected versus Observed Difference between TIP and GT Systems

	n TIP	γ TIP
TIP Instrument Uncertainty	2.6%	2.6%
Neutron & Gamma Correlation Unc.	4.0 – 4.5%	N/A
GT Calibration Uncertainty	1.9%	1.9%
Expected Difference (Uncertainty)	5.5%	3.2%
Observed Difference (RMS rd)	3.6%	4.5%

[[

]]

Table 9-14, Estimated Bundle Power Uncertainty ("reduced" model) (based on Tokai 2 In-Plant Test)

	n & γ TIP	GT (number of sensors)		
		9	7	4
TIP Integral	**2.71%**	**2.71%**	**2.71%**	**2.71%**
Four Bundle Power Distribution	**1.56%**	**1.56%**	**1.56%**	**1.56%**
LPRM Update Uncertainty	**0.30%**	n/a	n/a	n/a
Failed TIP	**0.53%**	n/a	n/a	n/a
Failed LPRM	**0.1%**	n/a	n/a	n/a
GT Integral Update Uncertainty	n/a	**0.20%**	**0.23%**	**0.30%**
GT to n TIP Bundle Uncertainty	n/a	**1.10%***	**1.10%***	**1.10%***
Additional Bundle Uncertainty	n/a	n/a	**~0%**	**~0%**
Failed GT Heater Wire	n/a	**~0%**	**~0%**	**~0%**
Failed GT Sensor	n/a	**~0.1%**	**~0.1%**	**~0.1%**
Total Uncertainty	**3.19%**	**3.32%**	**3.32%**	**3.33%**

[[

]]

* Estimate based on two GT strings: additional data is required for application.

Table 9-15, Estimated Bundle Power Uncertainty ("reduced" model) (based on Kashiwazaki-Kariwa 5 γ scan)

	n & γ TIP	GT (number of sensors)		
		9	7	4
TIP Integral	2.71%	2.3%	2.3%	2.3%
Four Bundle Power Distribution	1.56%	incl.	incl.	incl.
LPRM Update Uncertainty	0.30%	n/a	n/a	n/a
Failed TIP	0.53%	n/a	n/a	n/a
Failed LPRM	0.1%	n/a	n/a	n/a
GT Integral Update Uncertainty	n/a	0.20%	0.23%	0.30%
GT to n TIP Bundle Uncertainty	n/a	n/a	n/a	n/a
Additional Bundle Uncertainty	n/a	n/a	~0%	~0%
Failed GT Heater Wire	n/a	~0%	~0%	~0%
Failed GT Sensor	n/a	~0.1%	~0.1%	~0.1%
Total Uncertainty	3.19%	2.3%	2.3%	2.3%

10. CONCLUSIONS

The Gamma Thermometer System has been successfully evaluated as a replacement for the TIP system by a comprehensive In-Plant Test Program. The primary objectives of the Test Program have been met:

1. GT sensor accuracy relative to gamma TIP, neutron TIP and LPRM measurements has been evaluated; and

2. GT sensor reliability under BWR operating conditions has been established.

The GT sensitivity trends have been followed throughout a total of three cycles of operation at two BWRs. The sensitivity trend in the most recent test consisted of a relatively rapid initial rise during the first 500 hours of operation, followed by a slow decline for the rest of the cycle.

The GT response in the steady state has been compared with gamma TIP and neutron TIP response as well as the LPRM response. The GT response during changing conditions (startup, flow change, control blade change and power down) has been compared with the LPRM response. Additionally, a GT adaptive core monitoring study has been performed to compare nodal power, CPR and LHGR with corresponding results from neutron TIP adaption.

The GT sensors were evaluated for accuracy with a combination of factory, in-plant and core monitoring tests:

1. The factory tests proved that the GT sensors met all of the requirements of the SRS.

2. The in-plant tests proved the accuracy, linearity and range of the GT sensors with respect to the TIPs and LPRMs.

3. The core monitoring accuracy tests, including nodal power, CPR and LHGR, ascertained GT core monitoring accuracy with respect to neutron TIP monitoring. In addition, core monitoring simulations determined the minimal loss of accuracy in a GT system due to the limited number of readings in the axial direction, as opposed to the nodal data provided by a TIP system.

The overall conclusion of the GT in-plant test program is:

The GT system can be used in place of a TIP system for both LPRM calibration and power shape monitoring.

REFERENCES

1. R.H. Leyse, R.D. Smith: "Gamma Thermometer Developments for Light Water Reactors," IEEE Transactions on Nuclear Science, Vol.N5.26, No. 1, February 1979, pp. 934–943.

2. F. Loisy, M. Huver, M. Janvier: "Technology and Use of Gamma Thermometers," Specialist Meeting on In-Core Instrument Proceedings, France, June 1988.

3. "Power Distribution Uncertainties for Safety Limit MCPR Evaluations," NEDC-32694P-A, January 1997.

4. H. Shiraga, et al., "Verification of Core Monitoring System with Gamma Thermometer," International Conference on Global Environment and Advanced Nuclear Power Plants, GENES4/ANP2003, Sep. 15-19, 2003, Kyoto, Japan.

ENCLOSURE 1

MFN 05-079

NEDE-33179P, Gamma Thermometer System for LPRM Calibration and Power Shape Monitoring, Licensing Topical Report

GE Company Proprietary

PROPRIETARY INFORMATION NOTICE