

Operational Guidebook Development for FTIR Spectrum Two and Rotavapor R-300 Instruments in the Chemistry Research Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya

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ABSTRACT

Keywords:

Laboratory Instrument
Research and
Development
Validity
Practicality

The advancement of modern laboratory instruments has a significant impact on the quality of research in the field of chemistry. The Chemistry Research Laboratory of the Faculty of Mathematics and Natural Sciences (FMNS), Universitas Negeri Surabaya (UNESA), has important instruments, such as the PerkinElmer FTIR Spectrum Two and the Buchi Rotavapor R-300, but their use still faces obstacles due to the lack of practical guidance that suits the needs of learning and research. This study aims to develop a structured, contextual, and easy-to-understand internal operational guidebook to support the use of both instruments. The research method employed is Research and Development (R&D), adapted from the Borg & Gall model, which consists of five stages: product analysis, initial product development, expert validation, small-scale trials, and large-scale trials. Three expert lecturers conducted validation, while trials were conducted with laboratory assistants and chemistry students. The validation results showed an average score of 4.90 (very valid category). Small-scale trials conducted with laboratory assistants yielded a 100% positive response, while large-scale trials involving students achieved an average of 96% (classified as very practical). practicality observations showed a percentage of 100% for laboratory assistants and 98% for students in the very effective category. Thus, the developed operational guidebook has proven to be valid, practical, and effective, and can support occupational safety, enhance research quality, and strengthen UNESA's role as a leading center for the development of chemical science.

INTRODUCTION

Advances in science and technology, particularly in chemistry, are greatly influenced by the quality of laboratory instruments used in research activities (Chan et al., 2021; Reid & Shah, 2007). Researchers can conduct experiments and analyses more accurately and efficiently in laboratories equipped with advanced equipment, while also producing reliable data. The Faculty of Mathematics and Natural Sciences (FMNS), Universitas Negeri Surabaya (UNESA), through its Chemistry Research Laboratory, has modern facilities, including the Perkin Elmer Fourier Transform Infrared Spectroscopy (FTIR) Spectrum Two for infrared spectrum analysis (PerkinElmer, 2015), and the Buchi Rotary Evaporator (Rotavapor) R-300 for solvent evaporation (BÜCHI, 2017). These two instruments play a crucial role in supporting chemical research because they can provide in-depth data on molecular structure, compound identification, and sample purification (Aodah et al., 2023; El-Sheekh et al., 2022; Jenner et al., 2022; Leslie et al., 2022; Martinez et al., 2022; Salem & Fouda, 2021).

However, the use of these instruments requires a thorough technical understanding. Students and novice researchers often face difficulties operating these instruments due to the lack of practical guidance appropriate to laboratory conditions (Ramadhani, 2020).

Without clear guidance, operational errors can not only reduce the quality and accuracy of research results but also potentially cause damage to the valuable instruments (Zulianti, 2019). Official manufacturer guidelines are available; however, they are general in nature and do not always align with laboratory operational standards or the sample types commonly used at the FMNS UNESA.

The findings of the preliminary study indicate that most students encountered difficulties in comprehending the operational manuals of laboratory instruments, which are provided exclusively in English. The data revealed that 72% of respondents reported experiencing difficulties in reading and interpreting the content of the manuals. These challenges primarily arise from limited mastery of technical English terminology and the complexity of operational instructions that require both conceptual and procedural understanding. Consequently, many students needed additional time to translate the content independently or consult laboratory assistants to ensure accurate comprehension of the operating procedures. This situation has implications for reduced efficiency during laboratory sessions and an increased risk of operational errors that may affect the reliability and quality of analytical results.

Several previous studies support the need for clear and applicable operational manuals. Research by Cao et al. (2019) demonstrated that explanatory operational manuals, which provide explanations for procedures, can enhance user compliance with safety protocols. Research by Sunyata et al. (2022) also demonstrated that the presence of a practical manual can improve students' understanding of laboratory work procedures while minimizing operational errors. These findings align with research by Sunyata et al. (2023) which developed an operational manual for equipment in the Physics Learning Innovation and Practice Laboratory at UNESA. The results of the feasibility test, conducted through alpha and beta tests, fell into the "very feasible" category, with an average score of 88% for the alpha test and 83% for the beta test. It demonstrates that operational manuals play a significant role in enhancing instrument efficiency and preventing damage resulting from misuse.

Furthermore, research conducted by Hartanto et al. (2023) on the effectiveness of implementing Standard Operating Procedures (SOPs) during the transition from online to offline learning demonstrates that SOPs serve as an important tool in bridging the gap for students who are unfamiliar with the direct use of laboratory equipment. This situation highlights the need to develop an Internal Operational Guidebook that is structured, concise, and tailored to the specific needs of the UNESA chemistry research laboratory environment. This guide helps students and researchers use the instruments correctly, enhances the efficiency of the learning process, and minimizes the potential for costly errors. Furthermore, the availability of an easy-to-understand guide will accelerate the adaptation process for new users, enabling them to focus more on data analysis and interpretation rather than experimenting with the equipment.

Overall, the preliminary findings highlight the necessity of developing an Indonesian-language version of the operational manual that is contextual, communicative, and aligned with the terminology used in academic and laboratory settings. The availability of such a manual is expected to enhance the accessibility of technical information,

strengthen students' procedural understanding, and support the implementation of laboratory activities that are more efficient, safe, and compliant with established operational standards.

This study focuses on the systematic development of an operational guidebook for the FTIR Spectrum Two and Rotavapor R-300 instruments, followed by validation and user evaluation. Specifically, the study aims to describe each stage of guidebook development, evaluate its validity based on expert assessments, and determine its practicality through implementation trials involving students and laboratory assistants.

The research team developed an operational guideline that goes beyond the manufacturer's technical instructions by adapting its content to the specific educational and research needs of the Faculty of Mathematics and Natural Sciences (FMNS), Universitas Negeri Surabaya (UNESA). This guidebook is expected to make a significant contribution to improving research quality, enhancing laboratory safety, and strengthening UNESA's position as a competitive institution in the advancement of chemical sciences.

RESEARCH METHOD

This study uses the research and development (R&D) method proposed by Borg & Gall (1989). According to Sugiyono (2021), research and development (R&D) is a research method used to examine, design, produce, and validate specific products to create new products or improve existing ones, and test their practicality so that the broader community can use these products. In this case, the aim is to produce a valuable product in the form of an operational guidebook that facilitates the use of the PerkinElmer FTIR Spectrum Two and Buchi Rotavapor R-300 instruments in the Chemistry Research Laboratory of the FMNS UNESA.

Borg and Gall stated that there are 10 steps in the research and development process; however, in the Tim Puslitjaknov (2008), the research and development procedure according to Borg and Gall can be carried out more simply, involving five main steps, namely: (1) Analyzing the product. (2) Developing the initial product; (3) Expert validation and revision; (4) Small-scale field trials and product revision; (5) Large-scale field trials and final product. The steps in the development procedure are described as follows:

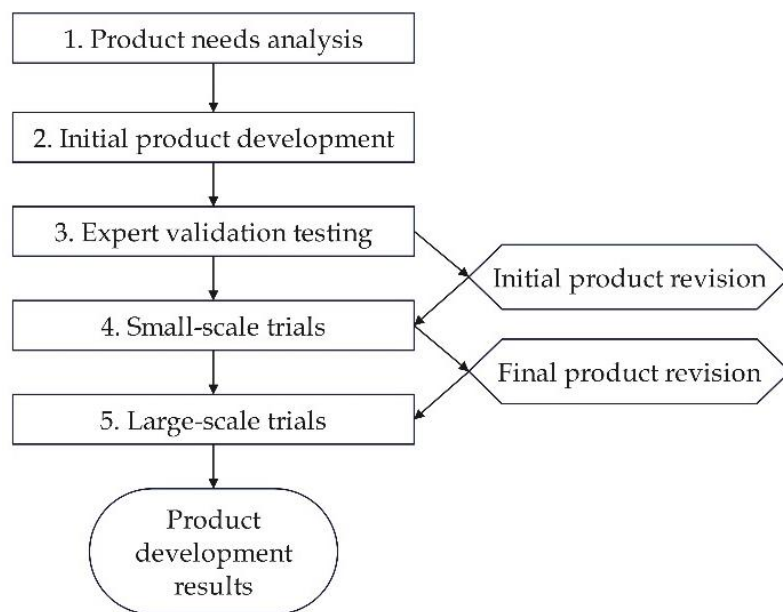


Figure 1. Procedures in Research and Development (R&D) (Tim Puslitjaknov, 2008)

The researchers conducted the research at the Chemistry Research Laboratory, FMNS UNESA. The reviewers evaluated the book's feasibility from three aspects: validity, and practicality. Researchers conducted data collection using questionnaires and observation methods. The questionnaire methods used were a validation questionnaire and a user response questionnaire. Researchers used the validation questionnaire to collect validation data. The validators consisted of three lecturers who were media experts and material experts. Researchers used the user response questionnaire to collect data to assess the validity and practicality of the developed operational guidebook. Researchers administered the user response questionnaire to users during the trial. In the small-scale trial, the sample consisted of three laboratory technicians from the UNESA FMNS research laboratory, who used the FTIR Spectrum Two and Rotavapor R-300 instruments. Laboratory technicians aimed to assess the guide's suitability in relation to the laboratory's technical procedures at this stage and ensure that existing instructions aligned with applicable operational standards. Then, in a large-scale trial, the sample consisted of 25 chemistry students from the FMNS UNESA, who utilized the FTIR Spectrum Two and Rotavapor R-300. Students were selected because they are the primary users in both practical and research activities, so their input reflects the extent to which the guide is understandable to beginners. Observers conducted observations throughout the trial. Observers observed every activity and behavior of the users. Researchers can use this method to assess the practicality of the developed operational guidebook.

The researchers analyzed the validation data from the developed operational guidebook quantitatively. Researchers used these results to determine the validity of the operational guidebook. Scoring was based on a Likert scale, as shown in Table 1.

Table 1. Likert Scale (Sugiyono, 2021)

Score	Criteria
5	Very Valid
4	Valid
3	Quite Valid
2	Less Valid
1	Not Valid

The assessment data were analyzed for each indicator using the mode. The operational guidebook was declared valid if it obtained a mode score of at least 4.

Researchers analyzed user response data quantitatively. The user responses in the questionnaire consisted of positive and negative statements. Scoring was based on the Guttman scale, as shown in Table 2 below.

Table 2. Guttman Scale (Riduwan, 2015)

Percentage (%)	Score	
	Yes	No
Positive	1	0
Negative	0	1

The data obtained were analyzed and accumulated using the following formula.

$$\text{Percentage of Practicality} = \frac{\text{Total score for each question}}{\text{Number of respondents}} \times 100\%$$

The results of the practicality percentage will be interpreted into scores based on the respective criteria, as shown in Table 3 below.

Table 3. Practicality Criteria Percentage (Riduwan, 2015)

Percentage (%)	Criteria
$0 \leq n \leq 20$	Not Practical
$21 \leq n \leq 40$	Less Practical
$41 \leq n \leq 60$	Quite Practical
$61 \leq n \leq 80$	Practical
$80 \leq n \leq 100$	Very Practical

Based on Table 3, a product can be declared practical or very practical if its practicality percentage is 61% or higher. Researchers will analyze user observation data quantitatively and score it based on the Guttman scale in Table 2. The data obtained will be analyzed and accumulated using the following formula.

$$\text{Percentage of practicality} = \frac{\text{Total score for each question}}{\text{Number of respondents}} \times 100\%$$

The results of the practicality percentage will be interpreted into scores based on the respective criteria, as shown in Table 4 below.

Table 4. practicality Criteria Percentage (Riduwan, 2015)

Percentage (%)	Criteria
$0 \leq n \leq 20$	Not practical
$21 \leq n \leq 40$	Less practical
$41 \leq n \leq 60$	Quite practical
$61 \leq n \leq 80$	Practical
$80 \leq n \leq 100$	Very practical

Based on Table 4, a product can be declared practical if its practicality percentage is 61 % or higher.

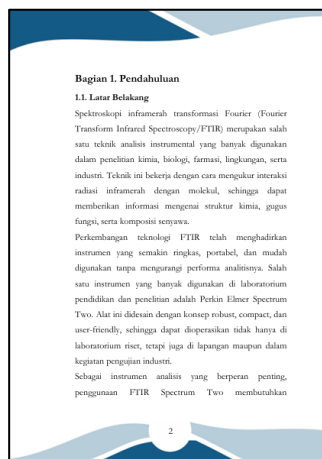
RESULTS AND DISCUSSION

A. Product Result

The product development in this research focused on Operational Guidebook for Fourier Transform Infrared Spectroscopy (FTIR) Perkin Elmer Spectrum Two and Buchi Rotary Evaporator R-300. This guidebook was meticulously designed as a comprehensive, systematic, and easy-to-understand operational reference with Indonesian language, aiming to guide users—including laboratory staff, lecturers, and students—in operating these two crucial instruments with proper and safe procedures. The resulting product is a 150-page guidebook containing integrated material, which covers the basic principles of the instruments, step-by-step Standard Operating Procedures (SOPs) for sample preparation and main equipment operation, essential safety information, and basic maintenance procedures.



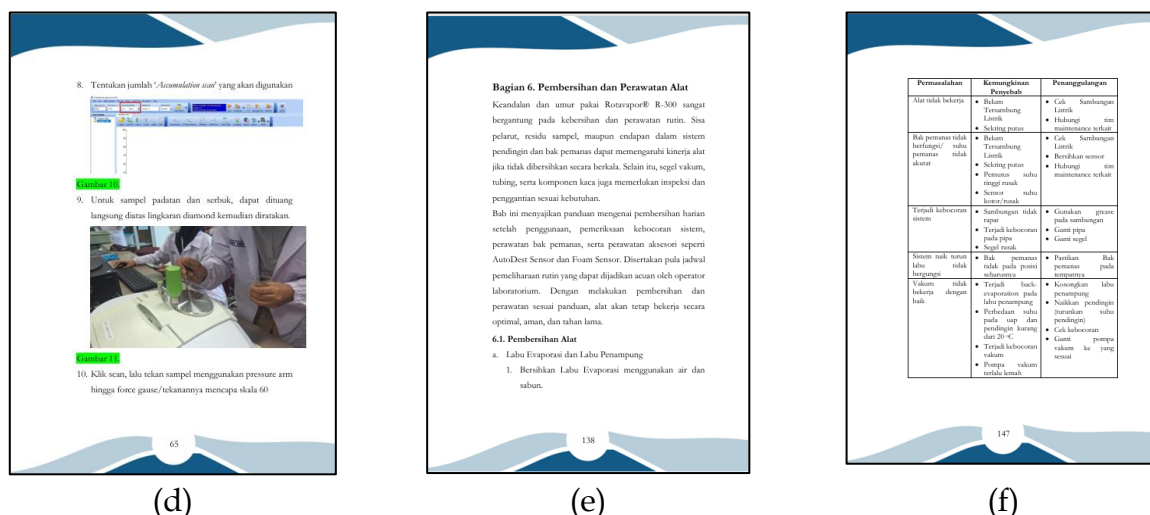
(a)



(b)



(c)



Picture 1. Some page views of Operational Guidebook for FTIR Spectrum Two and Rotavapor R-300

(a) Cover; (b) introduction to instrument; (c) Occupational Safety and SOP; (d) operational procedure; (e) Cleaning and maintenance; (f)troubleshoot

B. Expert Validation Results

Three chemistry lecturers conducted the validation and assessed the operational manual based on content, structure, language, presentation, graphics, color, font, and layout. Data were collected using a Likert scale (1–5), with a score of 5 indicating the highest validity. Table 5 below shows the validation results by three subject matter experts and a media expert.

Table 5. Validation Data by three Lecturers who are Subject Matter Experts and Media Experts

No.	Aspects Assessed	Average Rating of Validator			Average Rating of Each Aspect	Category
		Validator 1	Validator 2	Validator 3		
1	Content	5,00	4,78	4,89	4,89	Very Valid
2	Structure	5,00	5,00	5,00	5,00	Very Valid
3	Language	5,00	5,00	5,00	5,00	Very Valid
4	Presentation	4,33	5,00	4,67	4,67	Very Valid
5	Graphics	5,00	4,50	5,00	4,83	Very Valid
6	Color	5,00	5,00	4,50	4,83	Very Valid
7	Fonts	5,00	5,00	5,00	5,00	Very Valid
8	Layout	5,00	5,00	5,00	5,00	Very Valid
Overall average					4,90	Very Valid

The average assessment per validator represents the average score for each indicator. The assessors categorized the indicators according to the assessed aspects. For each assessed aspect, the expert lecturers scored the manual on a scale of 4 to 5, categorizing it as valid to very valid. For structure, language, fonts, and layout, the expert lecturers rated the operational manual as very valid. An average score of 4.5 or greater for each aspect is considered very valid. The overall average score is 4.9, indicating a very valid score. The expert lecturers limited their suggestions for improvement to minor areas: some image captions were missing, some abbreviations were missing, and some English text was missing from italics. Therefore, after this manual was revised, it was ready for small-scale testing, which will then be followed by large-scale testing.

B. User Response Results

The researcher obtained user feedback on the operational manual through two testing phases. The first phase was a small-scale trial involving three laboratory technicians. The second phase involved a large-scale trial using 25 students with the FTIR Spectrum Two and Rotavapor R-300 instruments. Table 6 below presents the results of user responses from the small-scale and large-scale trials.

Table 6. User Response in Small-Scale Trial (n=3)

No	Category	Statement	Number of "Yes"	Percentage	Category
1	Design	The book's cover design piqued my interest in reading the contents.	3	100%	Very Practical
2		The images, tables, and diagrams in the manual help clarify the work steps.	3	100%	Very Practical
3	Content	The manual aligns with the instruments available in the laboratory.	3	100%	Very Practical
4		The manual makes it easier for me to operate the instruments.	3	100%	Very Practical
5		The written procedures align with laboratory SOPs.	3	100%	Very Practical
6		The manual's material is detailed, systematic, and easy to follow.	3	100%	Very Practical
7		The manual aligns with the technical needs of daily laboratory work.	3	100%	Very Practical
8		The manual supports me in guiding students during practicums.	3	100%	Very Practical

No	Category	Statement	Number of "Yes"	Percentage	Category
9		The manual addresses safety aspects in the laboratory.	3	100%	Very Practical
10		Overall, this manual has been invaluable in operating the instruments.	3	100%	Very Practical
11	Language	The language used is clear, standard, and easy to understand.	3	100%	Very Practical
Average percentage				100%	Very Practical

Table 7. User Response in Large-Scale Trial (n=25)

No	Category	Statement	Number of "Yes"	Percentage	Category
1	Design	The book's cover design piqued my interest.	22	88%	Very Practical
2		The pictures, tables, and illustrations in the book helped me understand how the instruments work.	22	88%	Very Practical
3	Content	The manual aligns with the instruments I use in the laboratory.	25	100%	Very Practical
4		The manual made it easier for me to understand the procedures for using the instruments.	25	100%	Very Practical
5		The steps are detailed, coherent, and easy to understand.	24	96%	Very Practical
6		The manual can serve as a reference for independent study, eliminating the need for assistance from a lecturer or laboratory assistant.	22	88%	Very Practical
7		The manual helped me reduce errors in instrument use.	24	96%	Very Practical
8		The manual encouraged me to be more disciplined in adhering to standard	25	100%	Very Practical

		operating procedures (SOPs) and occupational safety.			
9		This manual is relevant to the needs of my practicums and research.	25	100%	Very Practical
10		Overall, this manual is handy in supporting my learning activities.	25	100%	Very Practical
11	Language	The language used is simple, straightforward, and compliant with EYD (Indonesian Spelling) rules.	25	100%	Very Practical
Average percentage				96%	Very Practical

Overall, the responses from laboratory technicians and students indicate that the manual has a high level of practicality, with an average score above 80%. Some students still considered the design to be improved, and the language of the manual needed to be simplified.

C. Results of Practicality Observation

Three laboratory technicians (in a small-scale trial) and 25 students (in a large-scale trial) conducted observations. Aspects observed included step accuracy, time required, and operational error rate.

Table 8. Results of Observation of Practicality in Small-Scale Trials (n=3)

No	Observed Aspects	Number of "Yes"	Percentage	Category
1	The respondent turned on the instrument according to the procedure (correct sequence).	3	100%	Very Practical
2	The respondent performed the initial calibration as outlined in the manual.	3	100%	Very Practical
3	The respondent wore PPE (mask, gloves, lab coat) while working.	3	100%	Very Practical
4	The respondent followed the operating instructions without skipping important steps.	3	100%	Very Practical
5	The respondent was able to handle simple errors by referring to the manual.	3	100%	Very Practical
6	The respondent turned off the instrument according to the instructions in the manual.	3	100%	Very Practical

7	The time required to complete the procedure met standards (efficient).	3	100%	Very Practical
8	The respondent maintained a clean and tidy work area after using the instrument.	3	100%	Very Practical
Average percentage			100%	Very Practical

Table 9. Results of Observation of Practicality in Large-Scale Trials (n=25)

No	Observed Aspects	Number of "Yes"	Percentage	Category
1	Students follow the instructions in the manual without asking questions to the laboratory assistant.	21	84%	Very Practical
2	Students follow the sequence of steps to use the instrument correctly.	25	100%	Very Practical
3	Students can understand the function of the instrument's buttons/features based on the manual.	25	100%	Very Practical
4	Students utilize the images/illustrations in the manual to understand the procedure.	25	100%	Very Practical
5	Operational errors (if any) can be corrected by referring to the manual.	25	100%	Very Practical
6	Students are trained in the proper use of PPE according to work safety protocols.	25	100%	Very Practical
7	The processing time is faster than before the manual process.	23	92%	Very Practical
8	The instrument is turned off according to the manual procedures.	25	100%	Very Practical
9	After the practical, students can explain the operational steps.	25	100%	Very Practical
10	Students leave the work area neat and safe.	25	100%	Very Practical
Average percentage			98%	Very Practical

The observations indicated that the manual's practicality ranged from 80% to 100%, categorized as very practical. The errors that emerged were generally minor, such as some students being confused or afraid to operate the instrument, which led them to ask the laboratory assistants numerous questions. Some students used the instrument for a slightly longer time than usual because they read the instructions first before operating the device.

D. Discussion

The results of the study indicate that the developed FTIR Spectrum Two and Rotavapor R-300 operational manual has a high level of validity. It is evident from expert assessments, which gave an average score of 4.90 on a Likert scale, categorized as valid to very valid. It means the manual meets the requirements of content, structure, language, presentation, graphics, color, fonts, and layout. These findings align with research by Sunyata et al. (2023), who developed a laboratory module in physics, where language and illustration were key factors in enhancing the suitability of learning media.

In terms of user response, a small-scale trial with three laboratory assistants demonstrated that the manual was practical to use, with an average positive response rate reaching 100%. It indicates that the manual fully meets the technical needs of the laboratory and supports the laboratory assistants in their work with students. In a large-scale trial involving 25 students, the average positive response rate was 96%, indicating that the manual significantly aided students in understanding the instrument's operating procedures. Some students still felt that they could improve the design and simplify the language. These results are consistent with research by Sunyata et al. (2022), which found that operational manuals can improve student understanding while minimizing errors in laboratory practice.

Observations on the practicality of manual use reinforced the questionnaire data. The results showed that students and laboratory assistants were able to follow the operating procedures, with 100% accuracy for laboratory assistants and 98% for students. The errors found were minor, such as some students being confused or afraid to operate the instrument, which led to numerous questions from the laboratory assistants. Some students used the instrument for slightly longer than usual because they read the manual before operating it. These findings are relevant to research by Hartanto et al. (2023), which emphasized the importance of SOPs as a supporting tool for laboratory learning, where students require systematic guidance to reduce operational errors.

CONCLUSION

Based on the research results, the researcher concluded that the operational manual for the FTIR Spectrum Two and Rotavapor R-300 instruments in the Chemistry Research Laboratory of the Faculty of Mathematics and Natural Sciences, UNESA, has proven to be highly feasible. The results of expert validation showed an average score of 4.90 on a Likert scale with a very valid category, which means the guide is appropriate in terms of content, structure, language, presentation, graphics, color, fonts, and layout. Small-scale trials conducted with three laboratory technicians yielded a 100% positive response, while large-scale trials involving 25 students achieved an average positive response of 96%. It indicates that the guide is easy to understand, practical to use, and helpful in supporting learning and research activities. In addition, the results of the observations showed relatively high practicality, with practicality rate of 100% among laboratory technicians and 98% among students. The operational errors that appeared were minor. Thus, this guide can be declared valid, practical, and effective for use as a supporting instrument for learning and research, while instilling a safe and disciplined laboratory work culture.

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