

NMR Macro Applications and Development to Streamline Workflows at INVISTA

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Introduction

As our ability to process, analyze and store data advances, so does our definition of what constitutes an efficient workflow. Solutions that were once effective time-savers can approach obsolescence at rates that are faster than expected. This can be brought about by a variety of internal and external factors, ranging from the evolving technological landscape, or a change in business requirements. In research and development, scientists devote substantial amounts of time on necessary, yet routine tasks. As a result, it is important to always consider how these workflows can be made more efficient within the time, budget and technological constraints.

Invista is one of the world's largest integrated producers of polymers and fibers, primarily for nylon, spandex and polyester applications. They deliver exceptional value for their customers through market insights, technology innovations and a powerful portfolio of global trademarks. INVISTA's Nylon Intermediates Plant, based out of Orange Texas, operate one of the world's leading adiponitrile (ADN) production facilities. Their research and development lab is driven by a talented team of engineers and scientists who support Koch Ind. companies worldwide. The facility uses a variety of analytical techniques that include: NMR, ICP-MS, XRF, FTIR, UV-Vis, UHPLC, and GC-MS.

The NMR facility records ¹H, ¹³C, ³¹P, and ¹¹B spectra of intermediate polymer research samples collected worldwide. Spectra are processed and the qualitative and quantitative results are returned to customers. For samples of known species, the purity is determined, and for unknown compounds, the structure is determined within given samples such as various Nylons, PTMEGs, glycols, polyols, terates and terols.

The steps performed to import data, process, analyze and create a report for this type of analysis by NMR are routine and repetitive. When performed manually, this process can be lengthy and is potentially subject to user errors. Furthermore, if the capability of the processing software is not meeting the user needs for compiling results and reporting, then at least one separate piece of software must be used for that.

Here we will show how INVISTA's Nylon intermediates plant implemented ACD/Labs NMR Workbook and a new workflow that reduces processing and reporting on a single spectrum from 20 minutes to 20 seconds.

An Improved Workflow

Historic Workflow

Prior to implementation of ACD/NMR Workbook, generating a report on the NMR analysis of a compound required 3 pieces of software: NUTs Software, MS Excel, and ChemDraw. As a result of historic data using NUTs, the accepted workflow consisted of:

1. Importing FID data into NUTs, manually phasing and flattening the baseline of the NMR spectrum, drawing integrals over relevant peaks, and copying the integrals to be pasted in MS Excel.
2. Creating tables in MS Excel for the copied integrals to be pasted
3. Drawing the structure in ChemDraw, choosing the relevant solvent, predicting its spectrum, and then pasting it into MS Excel to complete the report.

Total time to process, analyse and report: ~20 minutes per spectrum.

Figure 1 shows the two screens required to perform this workflow using NUTs, MS Excel and ChemDraw.

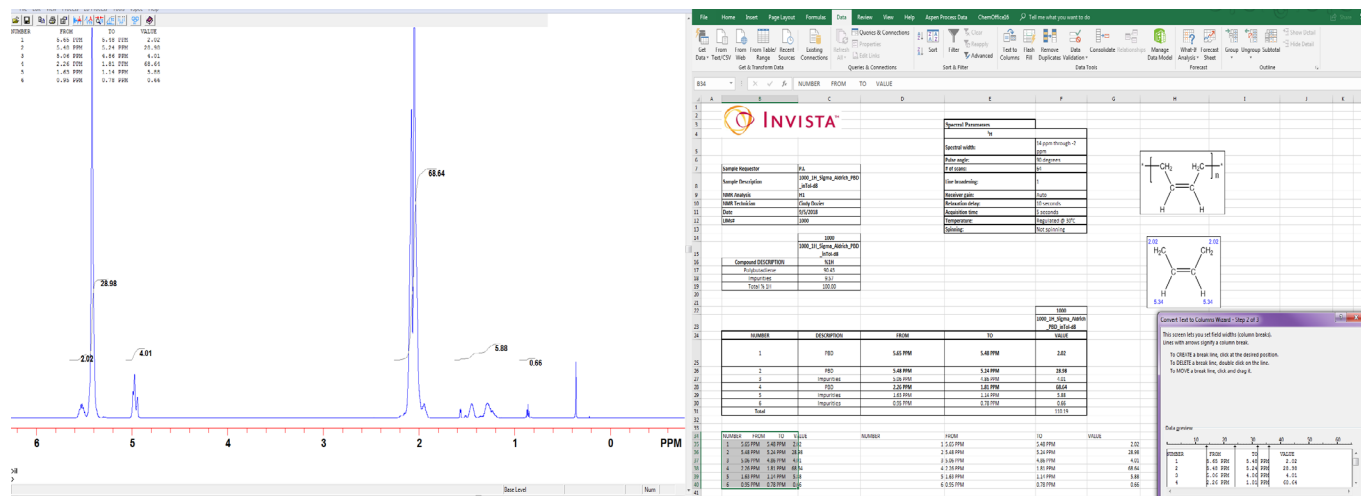


Figure 1. Screenshot of the workflow to process an NMR spectrum using NUTs, MS Excel, and ChemDraw

Improved Workflow

While the historic workflow was accepted, it required numerous manual steps, which exposed it to potential user errors. To expedite this process and increase confidence in the structures determined to match the NMR data, Cindy Dozier, an analytical chemist at INVISTA attempted to recreate results in a significantly shorter period of time using ACD/Labs NMR Workbook. The updated workflow proceeds as follows:

1. Import, process and integrate 15-16 NMR spectra simultaneously. For due diligence, the integrations are manually reviewed
2. Draw structure in ChemSketch and import it into NMR Workbook, where automated structure verification can be performed to ensure analytical accuracy

- Integrations are easily pasted into an MS Excel integration table. As an alternative, NMR Workbook can generate a comprehensive report and save spectra to a custom database. This negates the need for any software other than what is provided by ACD/Labs

Total time to process, analyze and report 1 spectrum: ~20 seconds

The main time saving aspects of this workflow are selecting pre-processing options and macros to apply to spectra upon import, and one-click automated structure verification. Spectra are processed upon import by selecting the desired pre-processing options in the menu shown in Figure 2.

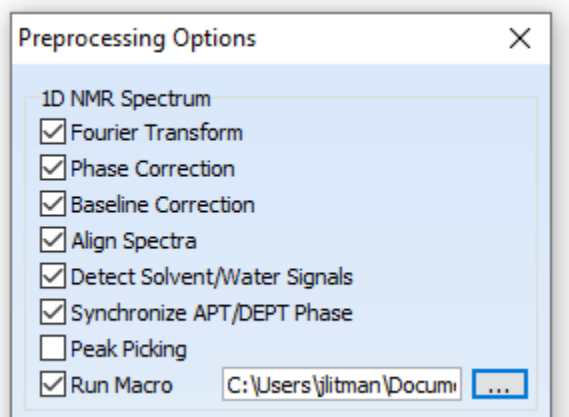


Figure 2. 1D Preprocessing options that can be applied to spectra upon import.

For the workflow described above, a fourier transform is applied to the FID, the spectra is then phase corrected and baseline corrected, and the desired macro upon is applied upon import. Macros can also be applied by clicking their respective shortcut button as shown in Figure 3.

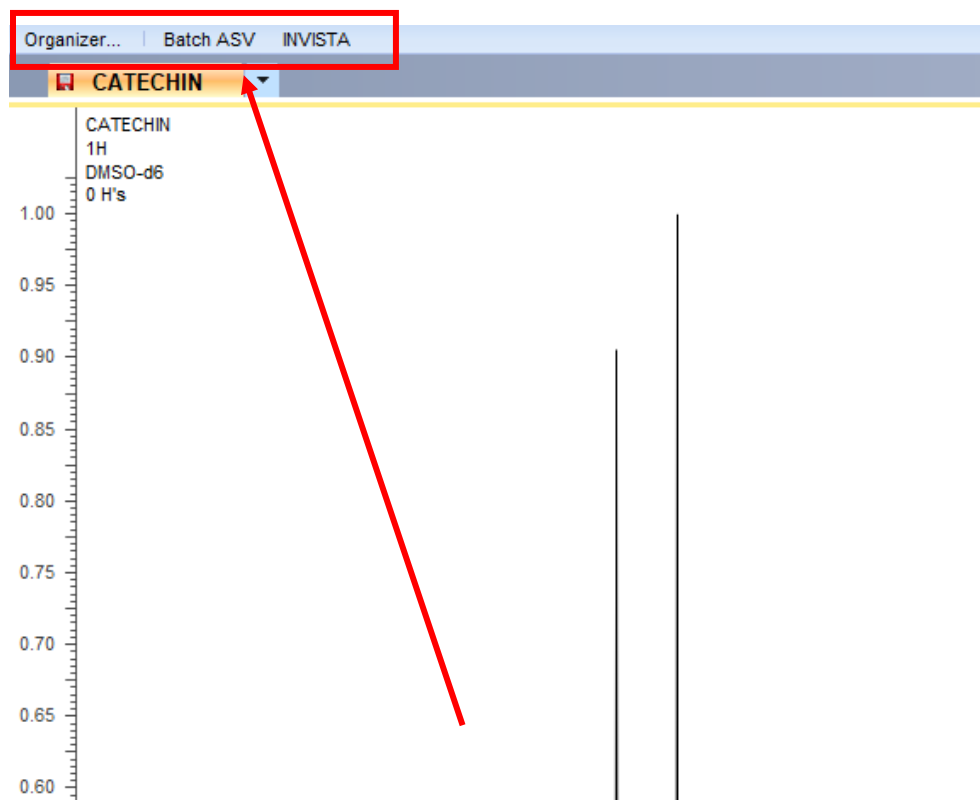


Figure 3. Macros are organized in their own tab for easy selection.

Finally, the automated structure verification (ASV) tool negates the need to predict a spectrum of the proposed structure and manually compare it to the experimental spectrum. ASV uses the ACD/Labs NMR Prediction algorithms to evaluate how well the proposed structure matches the experimental spectrum, and provides a numerical match factor to quantify the structure-spectrum agreement. This is shown in Figure 4. Match factors are values between 0-1, where 1 is a perfect match.

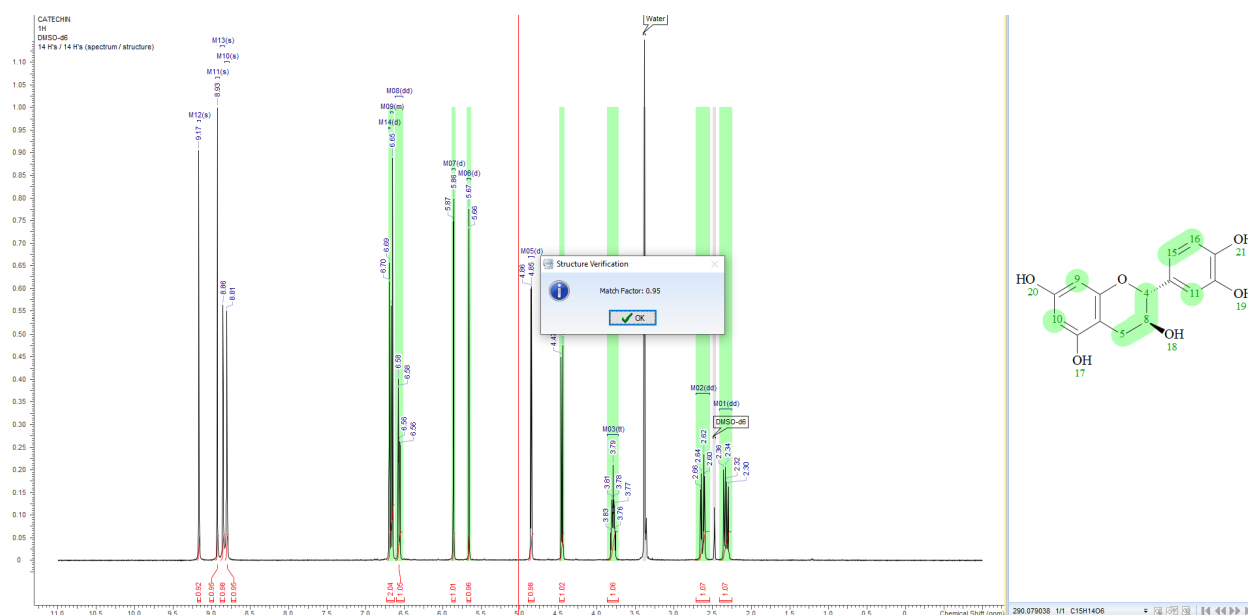


Figure 4. Comparison between the proposed structure and the experimental spectrum using the automated structure verification tool. The match factor is shown in the pop-up window upon completion.

Macro Creation

A component in expediting this workflow was using macros to automate the routine integration performed per NMR spectrum. Using macros for this purpose was effective since they can be written with minimal time investment. Creating a macro that integrates specified regions of a 1D NMR spectrum is a simple process that does not require any programming knowledge.

Figure 5 shows the steps in creating a new macro. After opening the macro organizer, located on the macros bar depicted in Figure 3, and selecting "New," the user can choose their desired functionality from a list of tools and define its parameters. Once the first command has been added, it is shown in the "Edit Macro" window. Additional commands may be added to the macro until it contains all of the user's desired functionality and is ready to be applied.

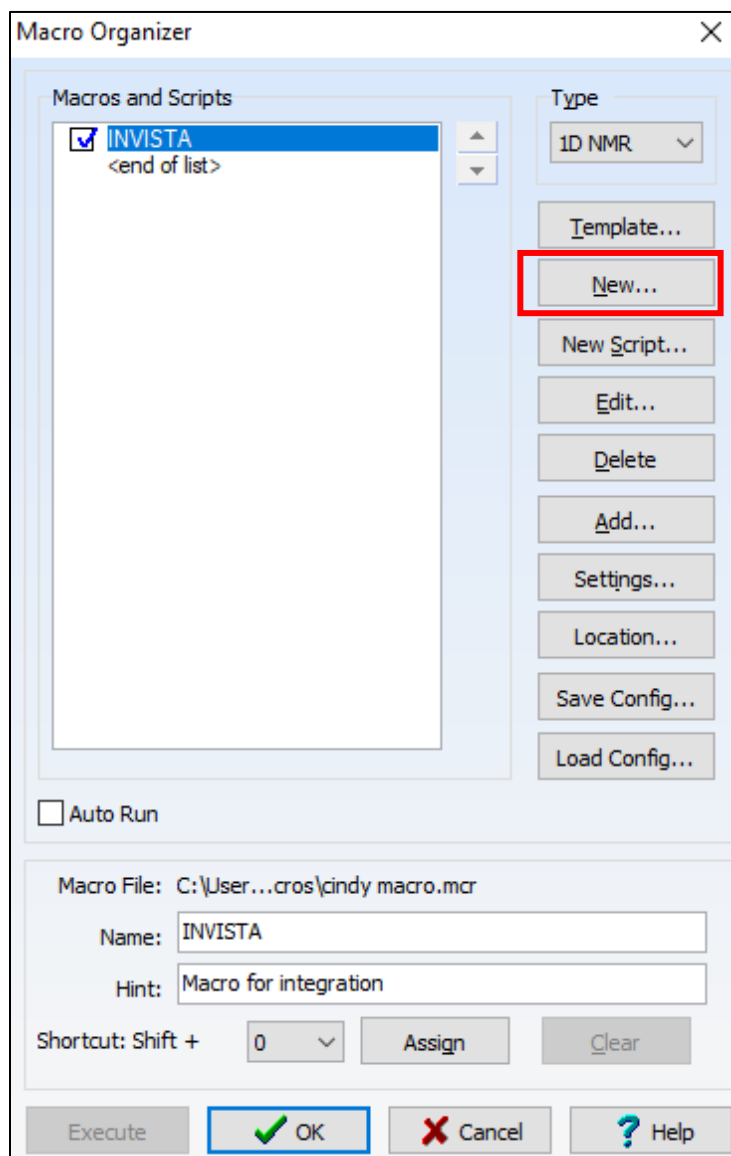


Figure 5(a). Open the Macro Organizer and select “New” to open the Edit Macros window. Be sure to define the type of spectrum the new macro is designed for, in this case it is a 1D NMR spectrum.

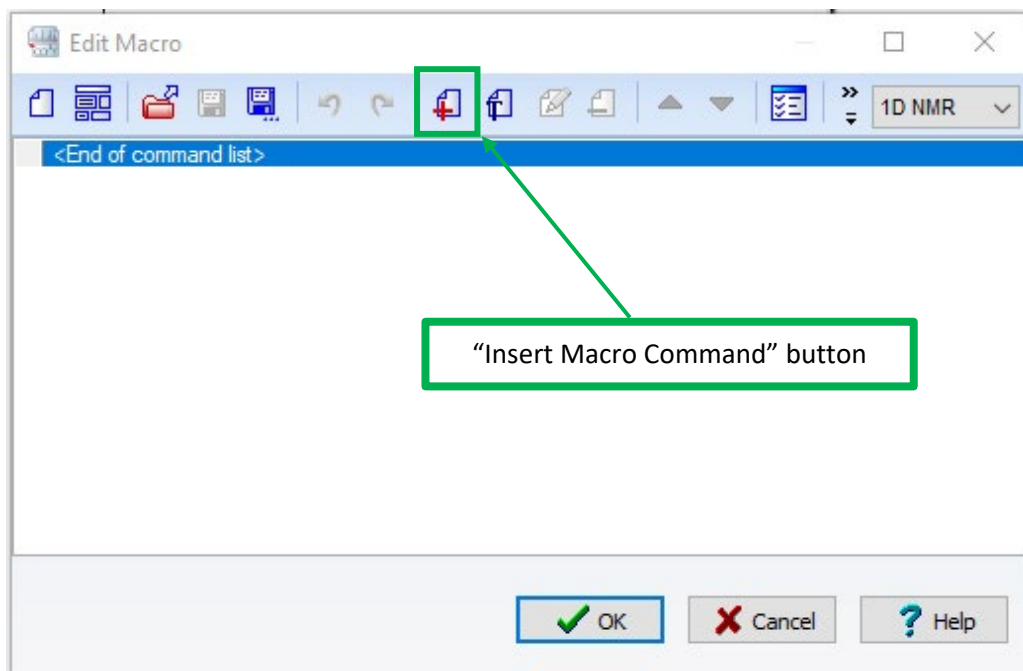


Figure 5(b). In the Edit Macro window, select the "Insert Macro Command" button to define the first function the macro will perform.

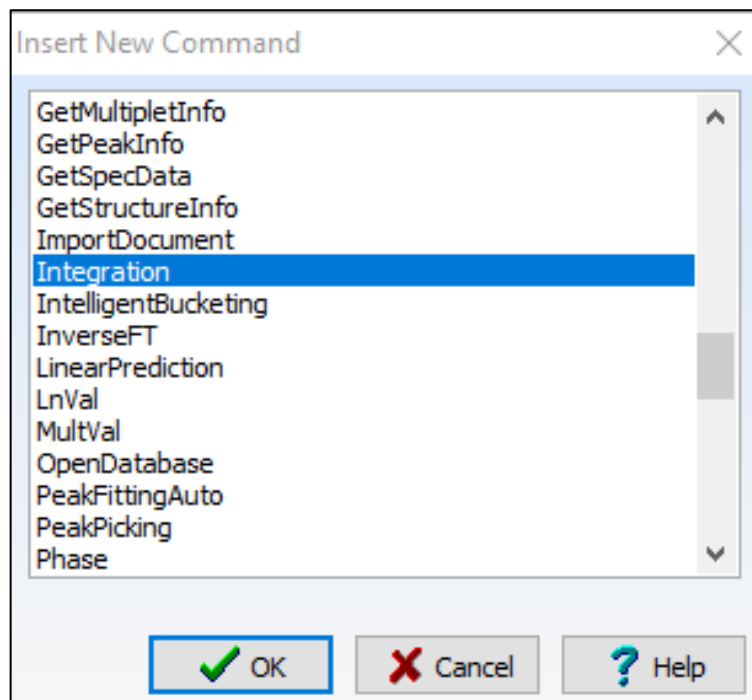


Figure 5(c).. Choose the first command of the macro from a list of pre-defined functions.

Integration Options

Auto Integration

Detect Signal Intervals Integrate Negative Signals

Noise Factor: Minimum Volume %:

Selected Interval

Range: - ppm Use Full Range

Use Intervals From File

File Name: ...

Reference

Reference Value:

Apply Reference Value to:

Whole Spectrum All Integrals Selected Integrals

Internal Standard Range: - ppm

Figure 5(d). Once a command has been selected, users are prompted to define its parameters

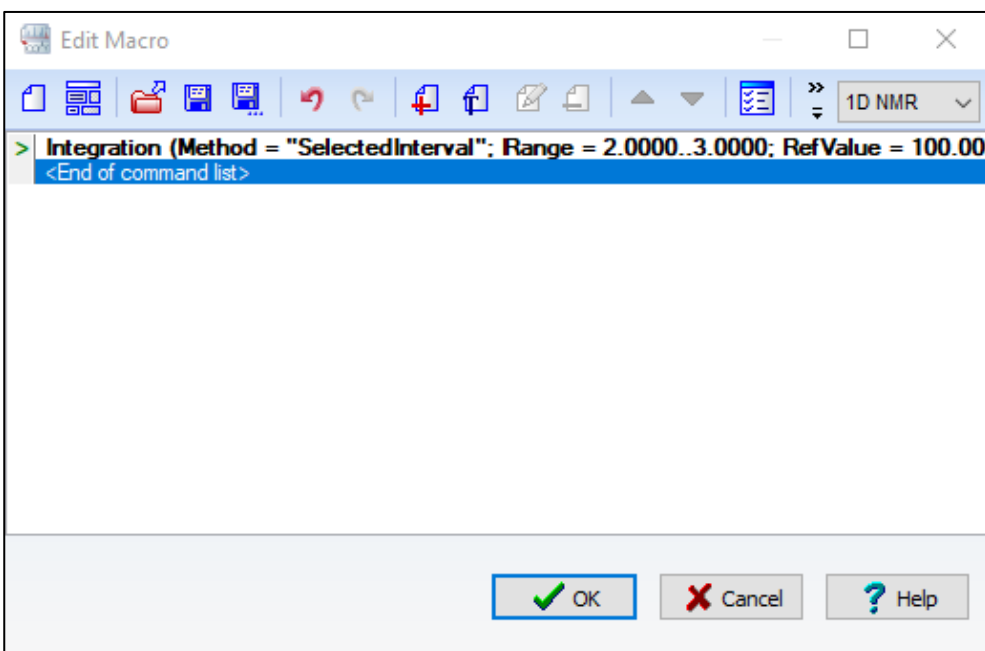


Figure 5(e). Once the initial macro command is added to the macro it can be viewed in the Edit Macros window. Additional commands can be added using the same workflow and re-ordered, if desired, in the Edit Macros window.

Conclusions

By implementing NMR Workbook, INVISTA's Nylon intermediates plant significantly increased the efficiency of their NMR analysis workflow. It both minimized the number of steps and pieces of software required to process, analyze and report an NMR spectrum. The methods described in this application note are broadly applicable to routine NMR analysis workflows and can be applied in many different contexts.