PSMA Core Loss Data Base

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WÜRTH ELEKTRONIK
MORE THAN
YOU EXPECT

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Working on application notes, seminars and software tools to help engineers use magnetics effectively. He has lifetime of experience that covers inductors small enough to pass through the eye of needle to industrial three phase control transformers and most everything in between. His experience includes quality control, automated manufacturing, automated testing and all aspects of power supply design and development.

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Progress over the past 40 years

In the past, the amount of data provided by core manufacturers on high-frequency B versus H loops and on core loss has been severely limited. Especially noticeable is the unavailability of data obtained under square-wave-voltage excitation which has special relevance for designers of switch-mode power supplies.

V.J. Thottuvelil, T.G. Wilson, H.A. Owen, Jr., “High-Frequency Measurement Techniques for Magnetic Cores”, 1985 IEEE Power Electronics Specialists Conference

How did we get here?

“Measurement is difficult. Consensus is even harder.”

Electrical Resistivity of Copper, Gold, Palladium and Silver

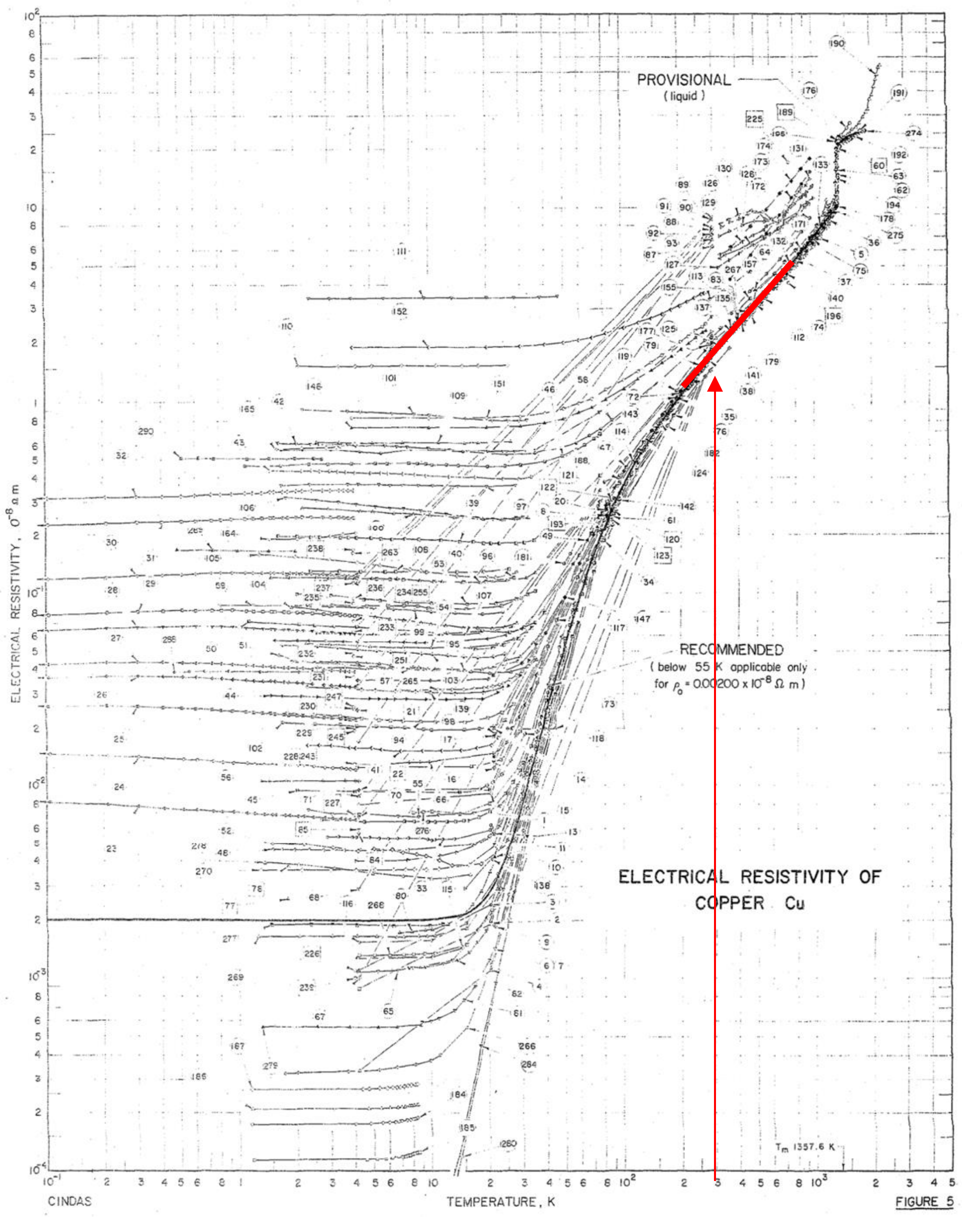
R.A. Matula

Center for information and numerical analysis and synthesis, Purdue University,

1979

- compiled from 290 sets of experimental data taken between 1881 to 1977 (96 yrs)

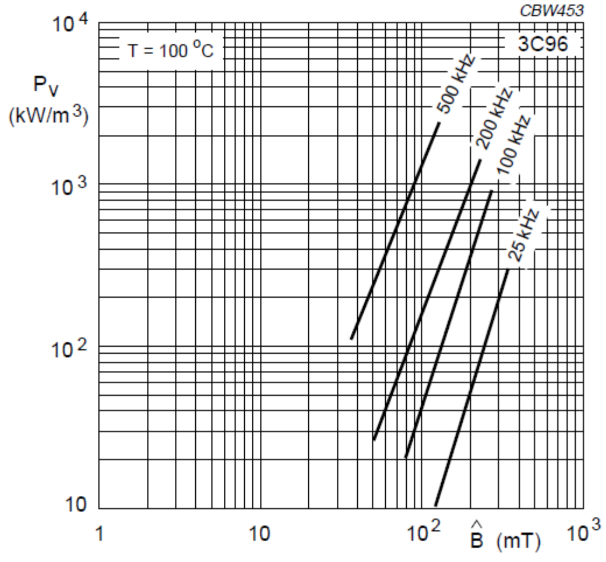
https://srd.nist.gov/JPCRD/jpcrd155.pdf

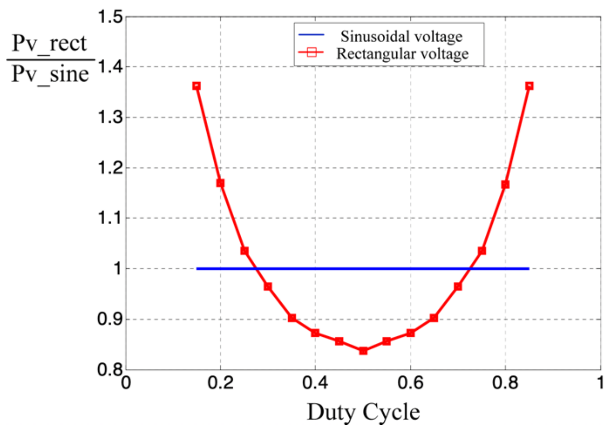


IS24.4

Why do we need this?

- Historically core loss data has been supplied by manufacturers:
  - On paper charts
  - Charts are usually small and the point you need is approximate
  - Listed in each vendor's catalog or website
    - Must look it up or create you own system
  - Based only on sine wave excitation
    - Hard to apply to switching power magnetics
  - Is the basis of comparison for all alternative methods
    - Papers proposing other methods use it as a reference but in reality, each vendor uses a different system which its unknown to the user





Ferroxcube Databook 2013 – 3C96
M. Mu, F.C. Lee, A New Series of High Frequency Core Loss Measurement Methods, PSMA Magnetics Workshop 2010

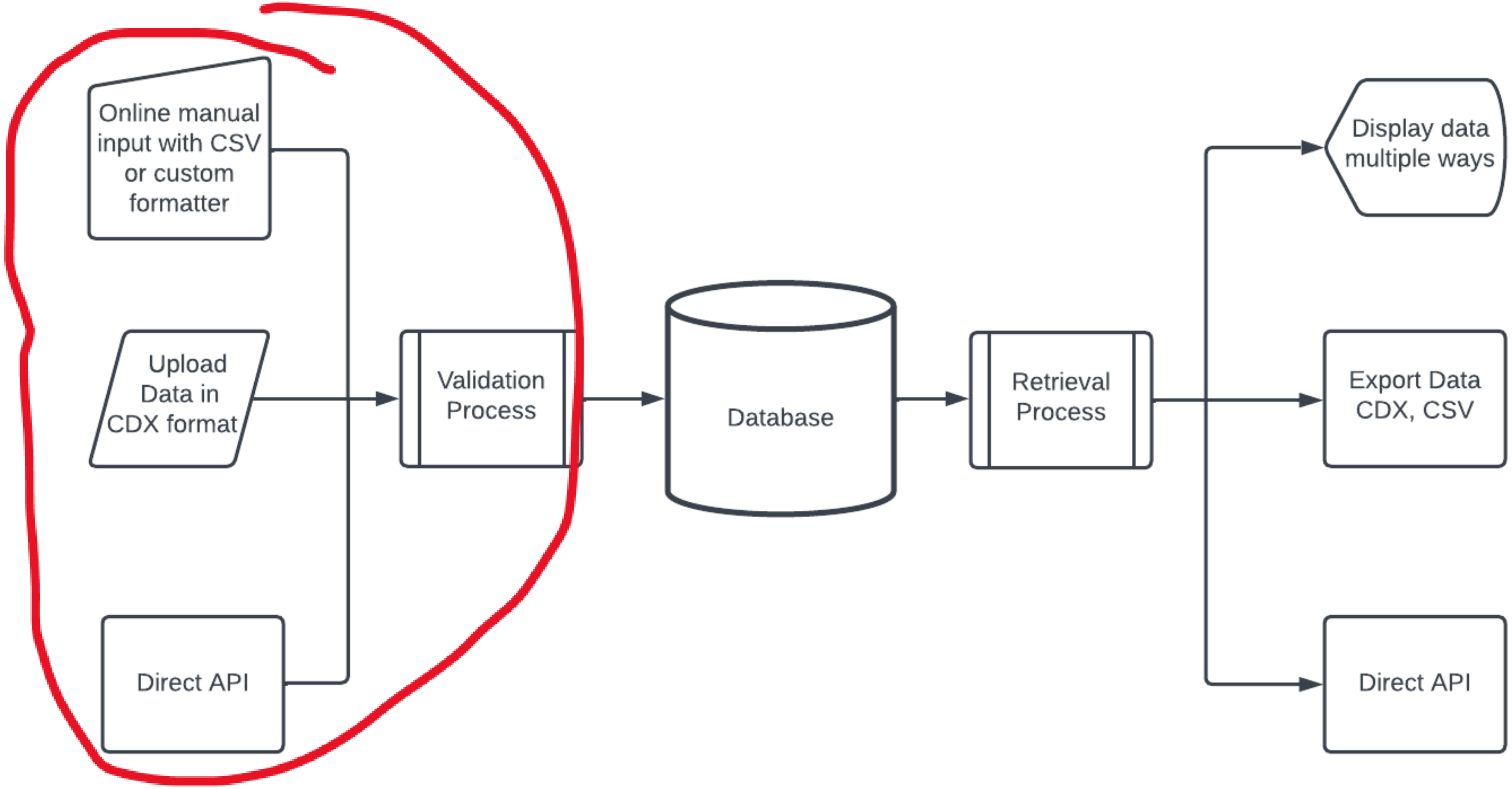
What are we doing?

- Creating an independent open-source website
  - Document, search, retrieve, organize and visualize core data
  - Any magnetic core material, size or shape
  - Reference standard setups, equipment, programs, people
  - Easy electronic data exchange

- Sponsored and sustained by the PSMA

- Updating *IEEE-393 Standard for Test Procedures for Magnetic Cores* to include:
  - Standardized V-I test method from 20 Hz to 20 MHz
  - Any magnetic core material, size or shape
  - Document the core data exchange (CDX) format
  - Includes references to IEC standards

How it works - Input



Looks like this

Core Data eXchange

gslama's Section | Logout

About | Upload Data | View Data | Resources

Upload data manually

Upload using web form

Upload your data from CSV

Upload CSV | Download CSV template

Upload your data from JSON

Upload JSON | Download JSON template | Data JSON Schema

Upload thorugh our API

```
pip install CoreDataXUploader
import CoreDataXUploader
CoreDataXUploader.upload_csv("your/csv/here.csv")
CoreDataXUploader.upload_json("your/csv/here.json")
```

Validation – The quality of data

Four levels of quality(uncertainity):

U – Undefined or partially defined
- setup/equipment is unknown/known/not disclosed

S – Specification bounded
- all equipment specifications are known and available
- allows calculating an outer bounding limit of uncertainty

C – Calibrated and compensated
- all of level S plus a calibration/compensation procedure
- narrows outer boundary of uncertainty

A – Golden sample
- all of level C plus comparison with a golden sample, calorimetric testing and averaging

Validation – The quality of data

Level D – unknown or undisclosed

- To accommodate existing or new data where:
  - the contributor does not know
  - or does not wish to disclose
- This could become a measure of reputation of the contributor

- The end user makes the judgement to suitability

Validation – The quality of data

Level C –specification based

- All equipment specifications are known and entered once
- Total uncertainty of signal path can be calculated by software
- Provides a known uncertainty boundary
- Automatically applied

Current channel 61I1	Current channel 61I2	Current channel 61I3
Plug-in unit for the connection of a triaxial shunt, a shunt adapter (for external high current shunts), the clamp-on transformer 61C1, or the LEM transducer set IT. Via a 9pol socket the shunts or transformers are identified automatically.	Like current channel 61I1 but with even higher angular accuracy. This current channel is used in the transformer version and in all applications that depend on high accuracy at small power factors.	Like current channel 61I1 but with lower measuring ranges. Thus results a higher dynamic range at current measurements in connection with the triaxial shunts.

61I1 Measuring range	61I1 Max. input DC, square	61I1 Max. input sine	61I2 Measuring range	61I2 Max. input DC, square	61I2 Max. input sine	61I3 Measuring range	61I3 Max. input DC, square	61I3 Max. input sine
50 mV_{PEAK}	50 mV_{RMS}	35 mV_{RMS}	50 mV_{PEAK}	50 mV_{RMS}	35 mV_{RMS}	15.8 mV_{PEAK}	15.8 mV_{RMS}	11.0 mV_{RMS}
158 mV_{PEAK}	158 mV_{RMS}	110 mV_{RMS}	158 mV_{PEAK}	158 mV_{RMS}	110 mV_{RMS}	50 mV_{PEAK}	50 mV_{RMS}	35 mV_{RMS}
500 mV_{PEAK}	500 mV_{RMS}	350 mV_{RMS}	500 mV_{PEAK}	500 mV_{RMS}	350 mV_{RMS}	158 mV_{PEAK}	158 mV_{RMS}	110 mV_{RMS}
1580 mV_{PEAK}	1580 mV_{RMS}	1100 mV_{RMS}	1580 mV_{PEAK}	1580 mV_{RMS}	1100 mV_{RMS}	500 mV_{PEAK}	500 mV_{RMS}	350 mV_{RMS}

Accuracy	Limits of error ± (% of rdg + % of rng)					
	Range 50 mV	Ranges 158...1580 mV	Range 50 mV	Ranges 158...1580 mV	Range 15.8 mV	Ranges 50 ... 500 mV
Frequency range	AC + DC		AC + DC		AC + DC	
0 Hz ...15 Hz	± (0.15 + 0.05)	± (0.15 + 0.03)	± (0.15 + 0.05)	± (0.15 + 0.03)	± (0.15 + 0.05)	± (0.15 + 0.03)
	(AC + DC) and AC		(AC + DC) and AC		(AC + DC) and AC	
15 Hz ...45 Hz	± (0.15 + 0.03)	± (0.15 + 0.01)	± (0.15 + 0.03)	± (0.15 + 0.01)	± (0.15 + 0.03)	± (0.15 + 0.01)
45 Hz ...1 kHz	± (0.04 + 0.02)	± (0.04 + 0.01)	± (0.04 + 0.02)	± (0.04 + 0.01)	± (0.04 + 0.02)	± (0.04 + 0.01)
1 kHz...100 kHz	±[(0.04+0.0045/kHz) +(0.02+0.0045/kHz)]	± [(0.04 + 0.0045/kHz) +(0.01+ 0.003/kHz)]	±[(0.04+0.02/kHz) +(0.02+0.0045/kHz)]	±[(0.04+0.0045/kHz) +(0.01+0.003/kHz)]	±[(0.04+0.0045/kHz) +(0.02+0.0045/kHz)	±[(0.04+0.0045/kHz) +(0.01+0.003/kHz)
100 kHz...400 kHz					typical: -1.5 % of rdg / 100 kHz	
400 kHz...1 MHz	typical: -2 % of rdg/100 kHz	typical: -1 % of rdg / 100 kHz				

	61I1	61I2	61I3
Additional error for measuring of peak values	Range 50 mV: ± 0.5% of rng Range 158 mV: ± 0.3% of rng Range 500 mV, 1,58V: ± 0.1% of rng	Range 50 mV: ± 0.5% of rng Range 158 mV: ± 0.3% of rng Range 500 mV, 1,58V: ± 0.1% of rng	Range 15.8 mV: ± 0.5%of rng Range 50 mV: ± 0.3% of rng Range 158 mV, 500mV: ± 0.1% of rng
Input impedance:	101 kΩ // 30 pF	101 kΩ // 30 pF	31,9 kΩ // 81 pF
Overload	250 V_{RMS} / 350 V_{PEAK} continuously (in all ranges)	250 V_{RMS} / 350 V_{PEAK} continuously (in all ranges)	25 V_{RMS} / 35 V_{PEAK} continuously (in all ranges)
Common mode rejection (CMR):	135 dB at 1000 V and 100 kHz	135 dB at 1000 V and 100 kHz	135 dB at 1000 V and 100 kHz

Angular error

Phase angle between voltage and current , in both channels AC+DC - mode, without LP-filter

Between current channel 61 I 1 and voltage channels			
Range	0...100Hz	100Hz...1kHz	Additional error
50mV	0.015°	0.020°	0.005°/kHz
158mV	0.005°	0.010°	0.005°/kHz
500mV	0.005°	0.005°	0.005°/kHz
1580mV	0.005°	0.005°	0.005°/kHz

Between current channel 61 I 2 and voltage channels				
Range	0...45Hz 65...100Hz	45Hz... 65Hz[1)]	100Hz... 1kHz	Additional error up to 10kHz
50mV	0.015°	0.002°	0.020°	0.005°/kHz
158mV	0.005°	0.002°	0.010°	0.005°/kHz
500mV	0.005°	0.002°	0.005°	0.005°/kHz
1580mV	0.005°	0.002°	0.005°	0.005°/kHz

Between current channel 61 I 3 and voltage channels			
Range	0...100Hz	100Hz... 1 kHz	Additional error
15.8mV	0.015°	0.020°	0.005°/kHz
50mV	0.005°	0.010°	0.005°/kHz
158mV	0.005°	0.005°	0.005°/kHz
500mV	0.005°	0.005°	0.005°/kHz

Validation – The quality of data

Level B - Calibrated

- Provide a process that checks the setup which is defined up to a calibration plane and repeatable
- The calibration plane is a test fixture
- Checked against easily obtained or built test structures
  - Similar to open, short, load calibration using voltage, current, phase and power
  - The user can do it by following a prescribed procedure
- Do repeatability and reproducibility study (R&R)
- This should narrow the uncertainty range from outer limits to nearer nominal

Validation – The quality of data

Level G – golden sample(s)

- Have golden samples to compare the system against other system's results – perhaps a golden average
- One of the other systems would be calorimetric
- There would need to be several types (ferrite, powdered cores, amorphous, laminations, etc.)
- There lots of logistical challenges:
  - Storing it, getting it shipped, getting it <u>back</u>
  - Possibility of losing or damaging it
  - Can there be more than one?
- Poor history of results

CDX format

- JSON based file format
- Fully expandable for future proofing
- Only use fields as needed
- Schema has required and optional data
- Human readable
- Supported in all computer languages

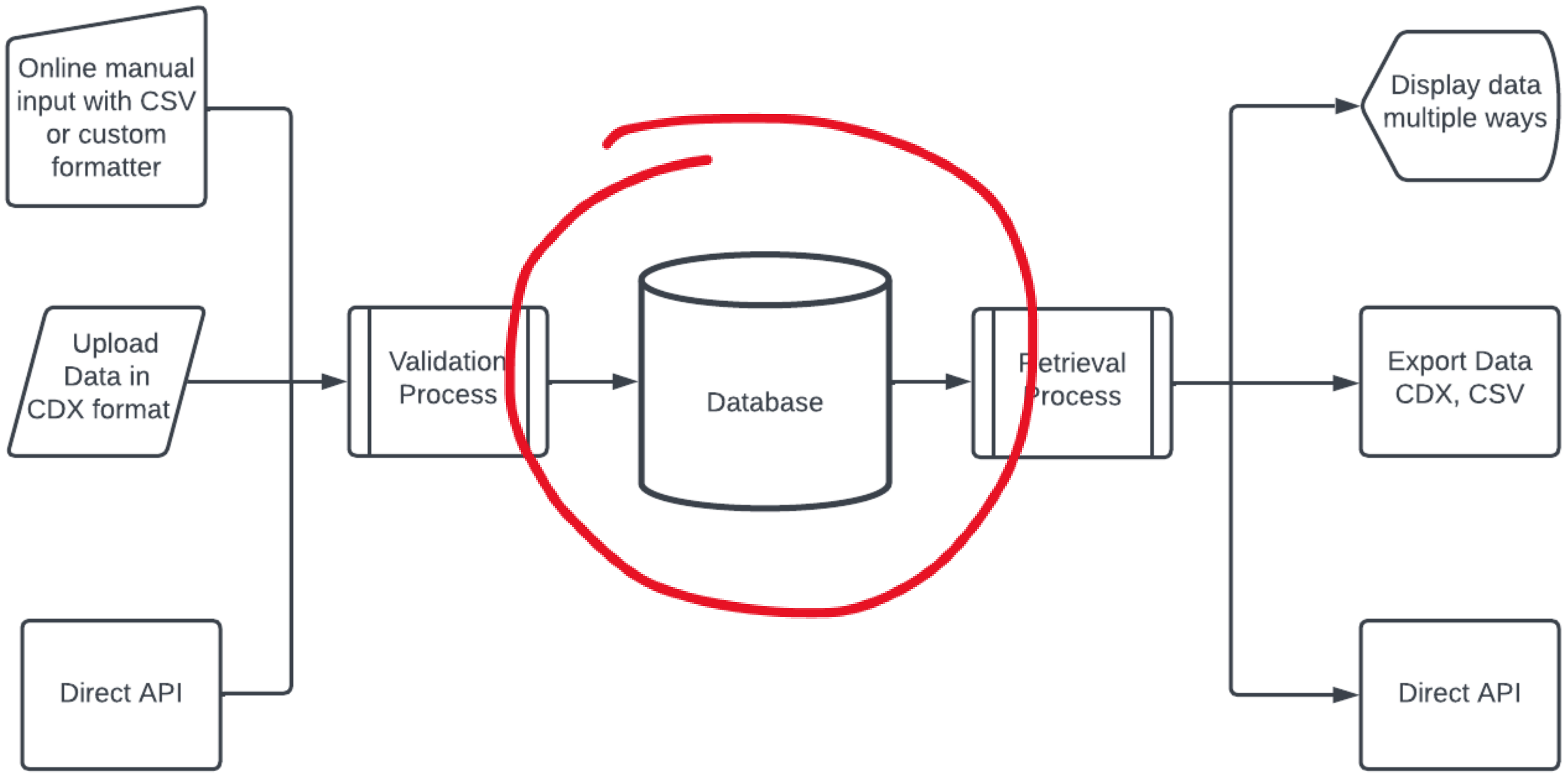

```json
{
  "$schema": "https://json-schema.org/draft/2020-12/schema",
  "$id": "https://coreDataX.com/cdx.schema.json",
  "title": "CDX JSON Data Format",
  "description": "draft data format definition for core loss data exchange
  "type": "object",
  "properties": {
    "metaData": {...},
    "testCircuit": {...},
    "equipmentList": {...},
    "sourceWaveForm": {...},
    "testData": {...},
    "calibrationData": {...},
    "processedData": {...}
  }
 }
}
```


Disadvantage

- A little longer than pure data


```json
"processed": {
    "label": "Triangular",
    "dutyCycle": 0.25,
    "peakToPeak": 10,
    "offset": -5.551115123125783e-17,
    "rms": 2.901747557746692,
    "effectiveFrequency": 129707.25838644087,
    "thd": 0.3821174090020204
},
```

How it works - The data



Database

- Stored for efficiency of search and retrieval
- No limit to the amount of data - infinitely expandable
- Storage and back up
- Does not need to store data in the same format as its imported or exported

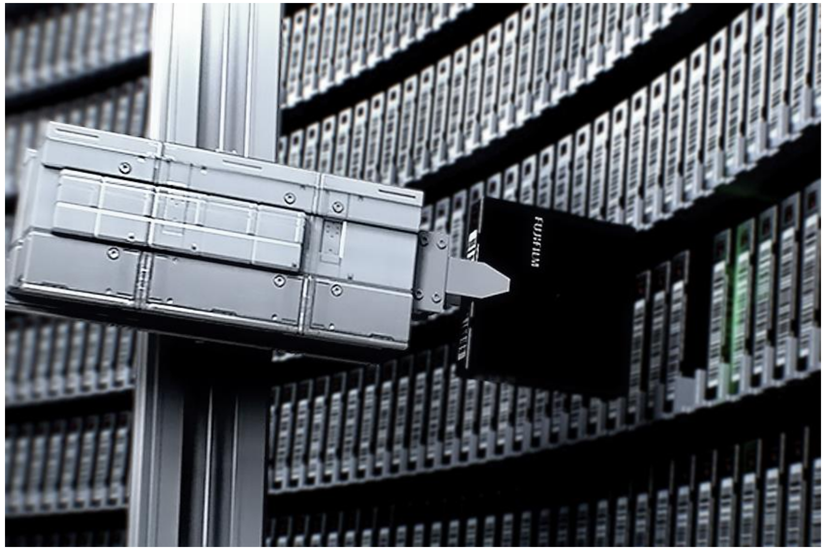
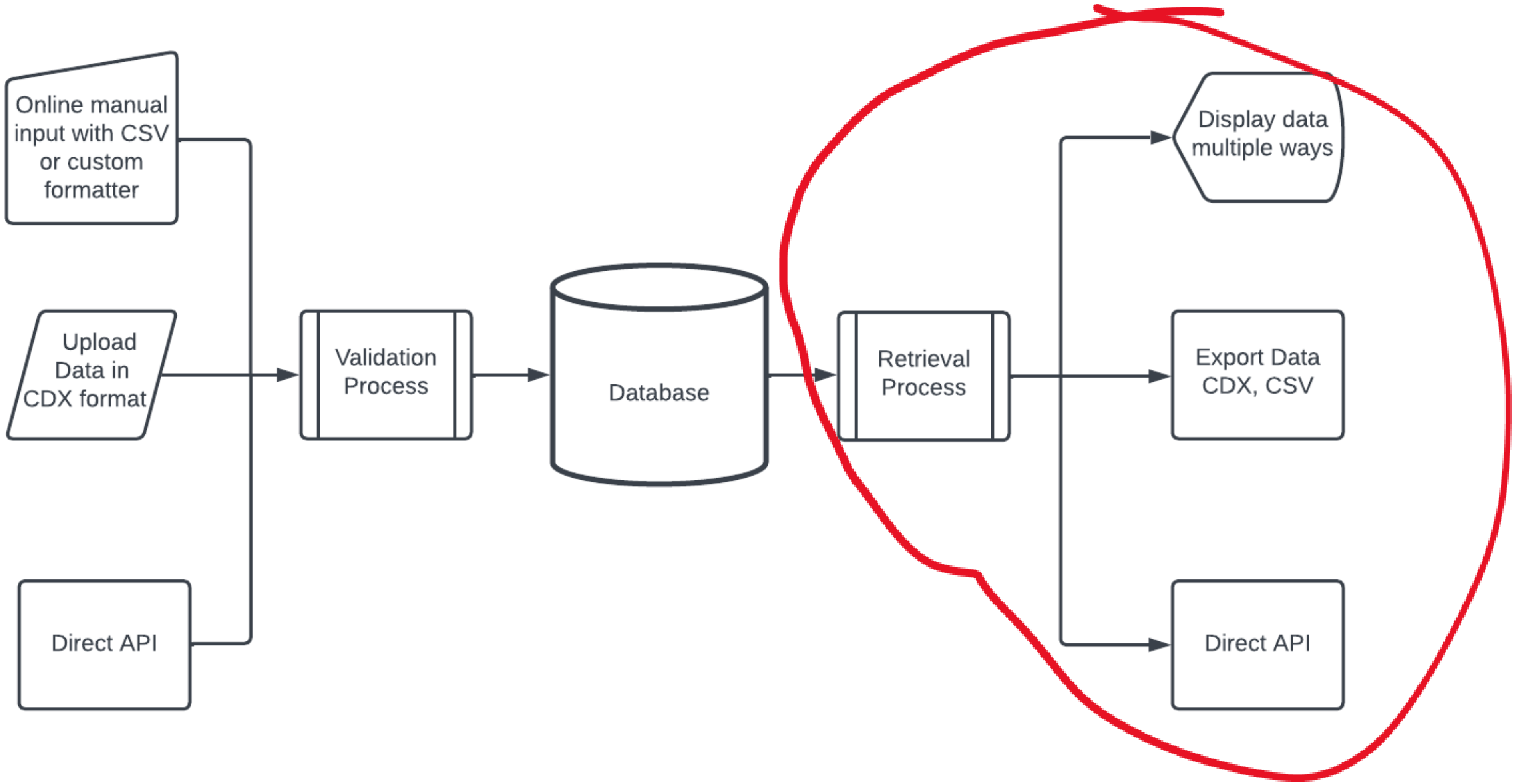


Image: https://www.tape-storage.net

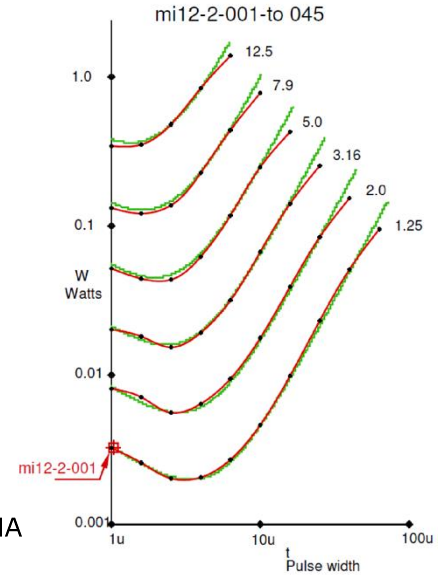
How it works - Output

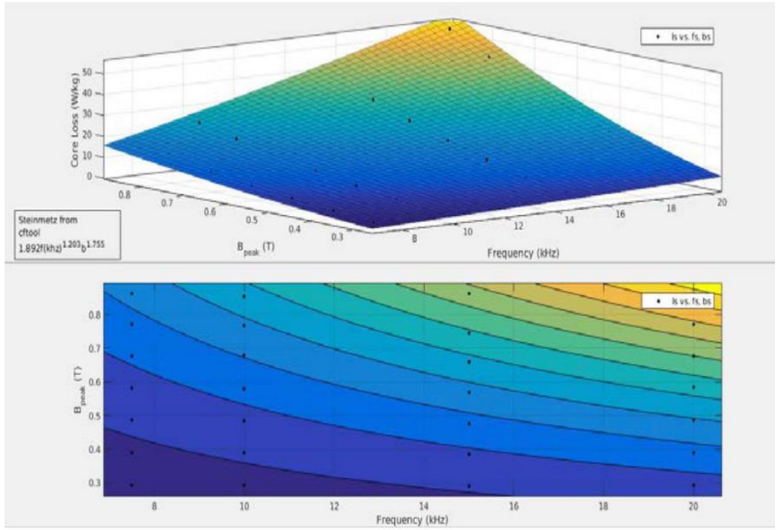


Viewing the data

- We provide a viewer where you
  - Can select contributor(s)
  - Can select x-axis
  - Can select y-axis
  - Can select material(s)
  - Can select conditions

- Open source means your imagination and programmability are the limit





E. Herbert, Core Loss Parameters, PSMA Magnetic Workshop 2017

R.B. Beddingfield, S. Bhattacharya, P. Ohodnicki, Multi-parameter Magnetic Material Characterization for High Power Medium Frequency Converters, PSMA Magnetics Workshop, 2018

Exporting the data

- Data can be exported
  - As a chart picture or as chart data
  - As a set (large or small)
  - CDX format with or without meta data
  - One basic CSV format with limited meta data

User community

- No registration to view or download data
  - Register to get updates (monthly)
- Contributing users need to register
  - Need to be able to contact them regarding their data

- The expectation is that interested users will also contribute and share their experience with others
  - Testing, methods, equipment, software
  - Software coding to for viewing data in new ways
  - Verification of data
  - Maintenance and expansion of the website

Timeline

- ✓ First milestone (ready for Christmas)
  - Basic web page
  - Database with existing data plus basic visualization running on server
- ✓ Second milestone (ready for APEC)
  - Registration
  - Personal and technical data (test benches and equipment) insertion
  - Uploading data through the web page, with manual data check
  - Server auto backup
  - Comparison of core materials, core shapes, and measurements
- Third milestone (ready for Summer, final date depending on APEC feedback)
  - Uploading data through API
  - Automatic data check in API and web
  - Advanced visualization

Thank you for your interest.

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