Near-infrared Instrument Networking: Design and Implementation

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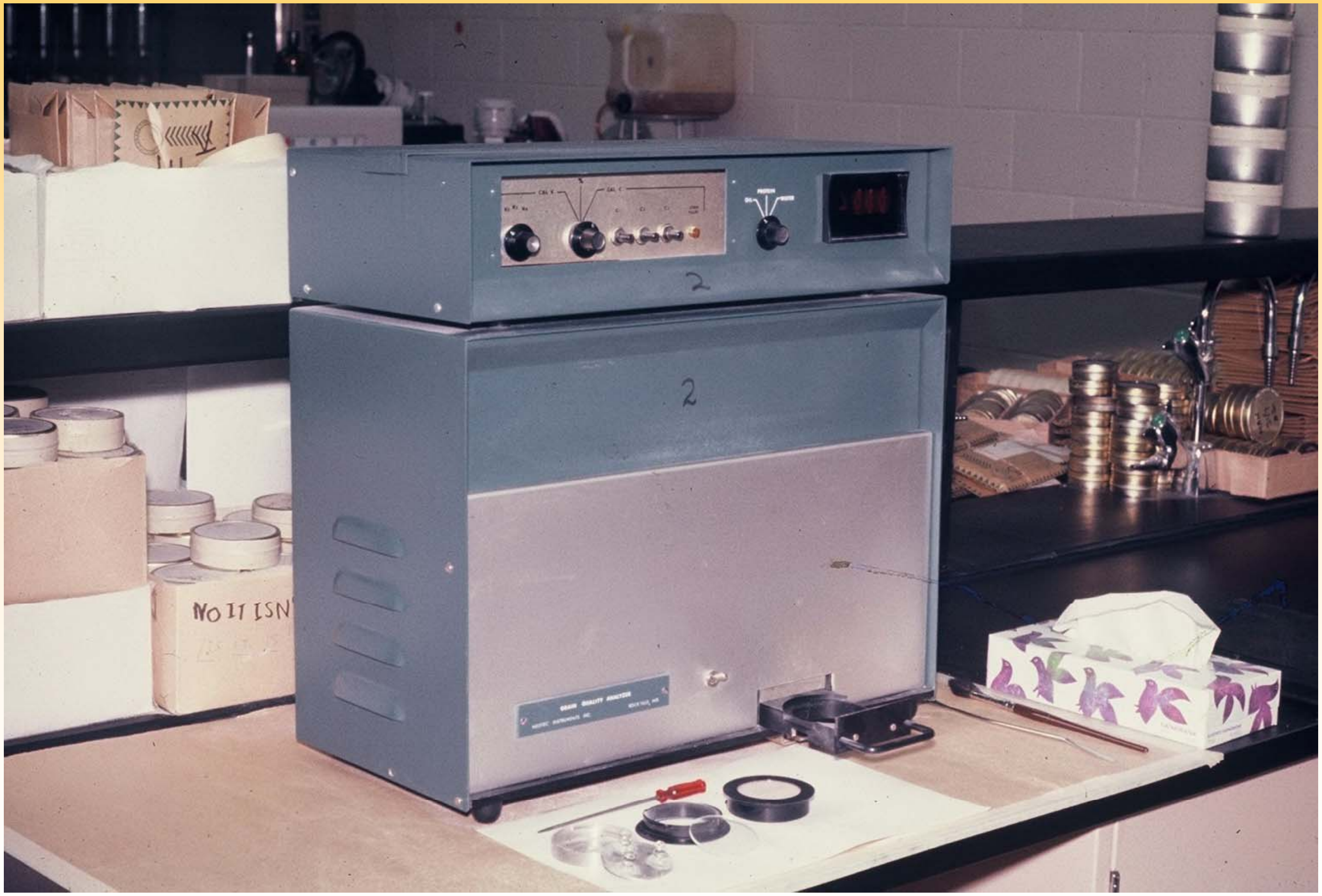
The Neotec Model I, 1972
(Where it all started!)



Networking: The Principles

- Networking is a way of extending and getting the maximum benefits from the application of NIR technology
- Instruments of the same type and model can be standardized and networked so that they all use the same calibrations, and operate with the same accuracy and precision
- Calibrations developed by one centre can be shared with other centres that use the same types and model of instruments

The Principles

- Networking allows the efficient operation of a series of NIRS instruments by staff that may be lacking in basic knowledge of the technology
- When an organization is operating several instruments they can all be managed using a networking system.
- The instruments can be monitored and controlled from a single personal or main-frame computer at a central laboratory or office

The Principles

- Networking means a series of instruments working together usually from a single control point to achieve the common goal of controlling an operation
- In the modern world of NIRS, with the proliferation of computers, networking also means a group of people working together to exchange ideas and information, to achieve the common goal of improving the efficiency of the operation

The Principles

- The ideal system enables control of analytical accuracy and precision by a central control laboratory or office
- The on-site operator may have no access to the system for adjusting the instruments
- Most large-scale networking operations have been developed in-house, by establishments involved with large-scale grain-handling
- Regrettably, mainly because of protection of intellectual property, there is little published information on NIRS network development

Prerequisites

- Successful application of near-infrared (NIR) networking depends on the reliability of ten factors:
  - the coordinator in charge of the networking operation
  - reference or “check” samples
  - a system for distribution and use of check samples
  - a dependable laboratory for reference testing
  - a set of reliable instruments with reliable calibrations

Prerequisites

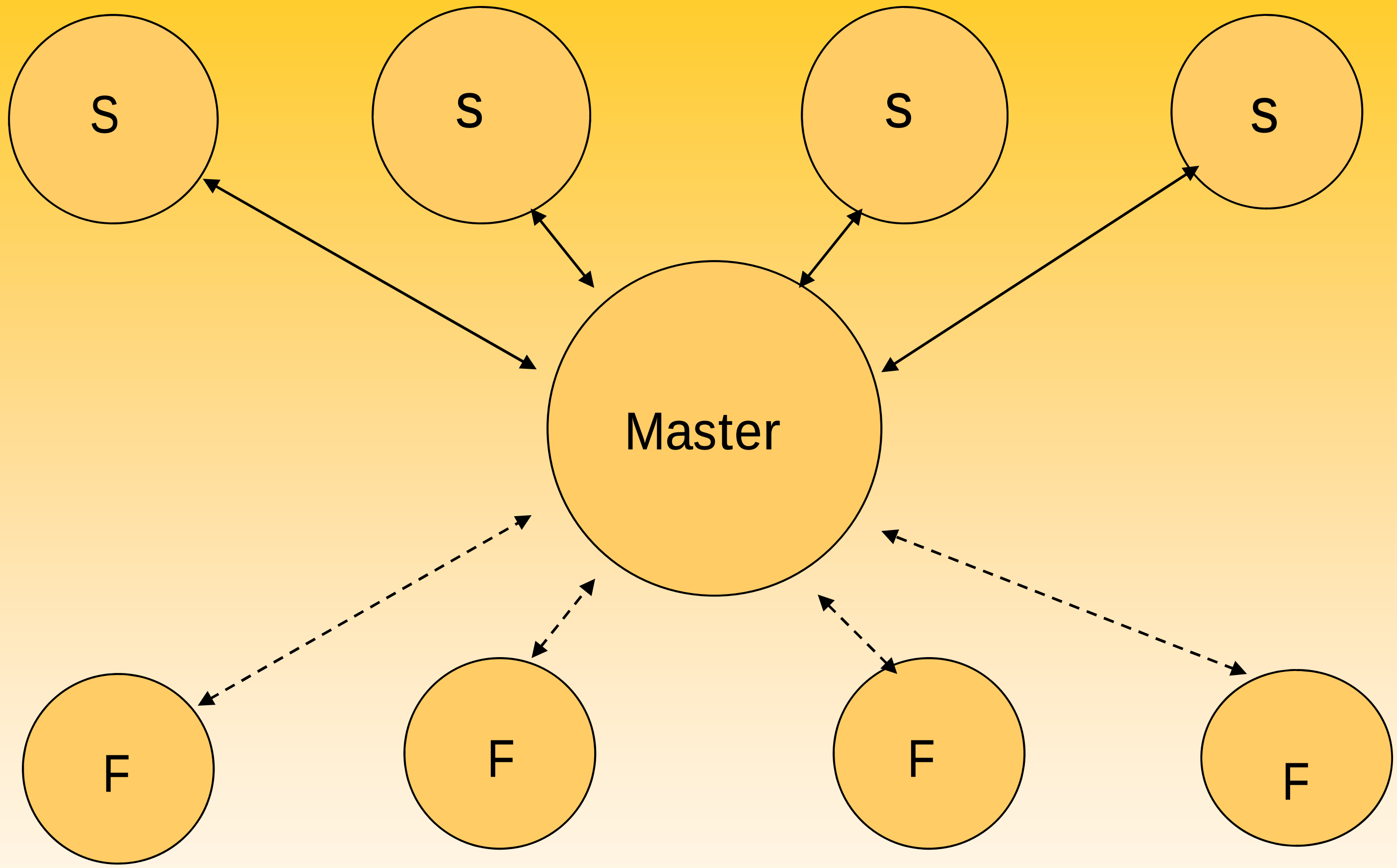
- a central computer (this can be a main-frame, PC, or a lap-top)
- software for monitoring purposes and applying corrections to instruments
- software for development of calibrations
- software for operation of the network
- education and training of staff in all aspects of the operation

Network Applications

- Networking applications can be divided into two main categories. These are:
  - control of the accuracy and precision of instruments
  - access to data throughout the network for control of the operation

Types of Networks

- There are three main forms of networks (not in order of importance)
- The first type consists of a series of instruments connected to a central computer
- The following slide illustrates this type. The S circles represent “satellite” instruments at delivery or shipping points. The F circles represent a series of flour mills, which can be controlled from the central computer as an optional service to the industry



The Networking concept:

Legend: Master = master instrument at central laboratory
S = “Satellite” instruments at wheat receiving points
F = Flour mills (optional participation)

Types of Networks

- The instruments would all be controlled from the master instrument, via the central computer, and the instruments monitored on-site by check samples
- The optional service to the mills would include supply of the same check samples used by the control centre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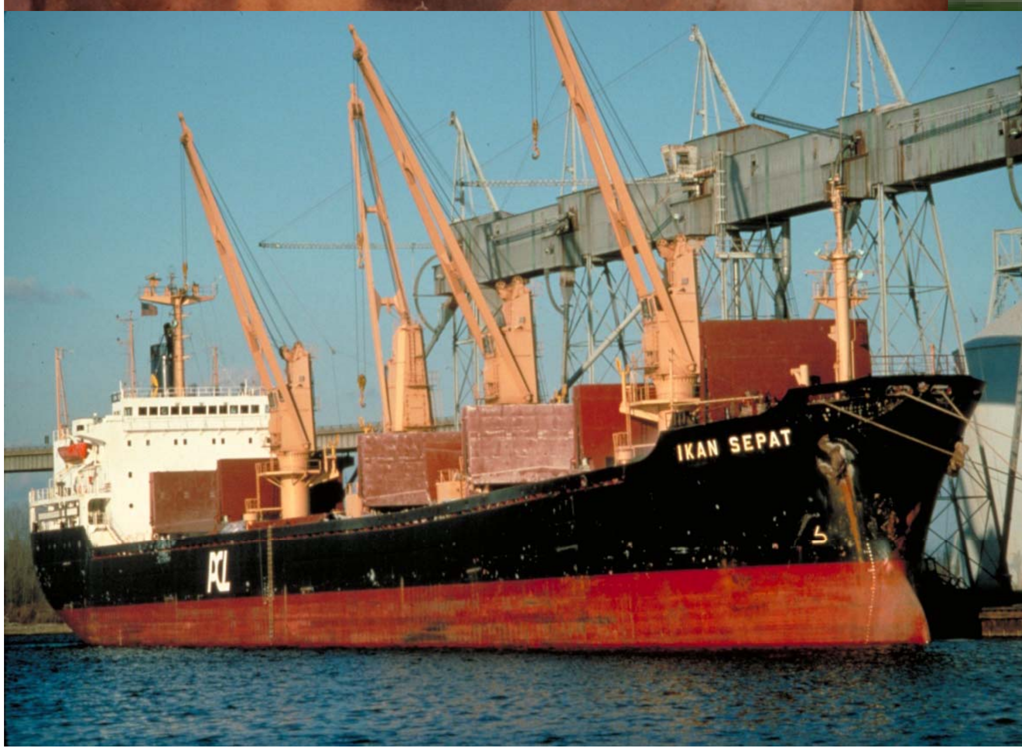
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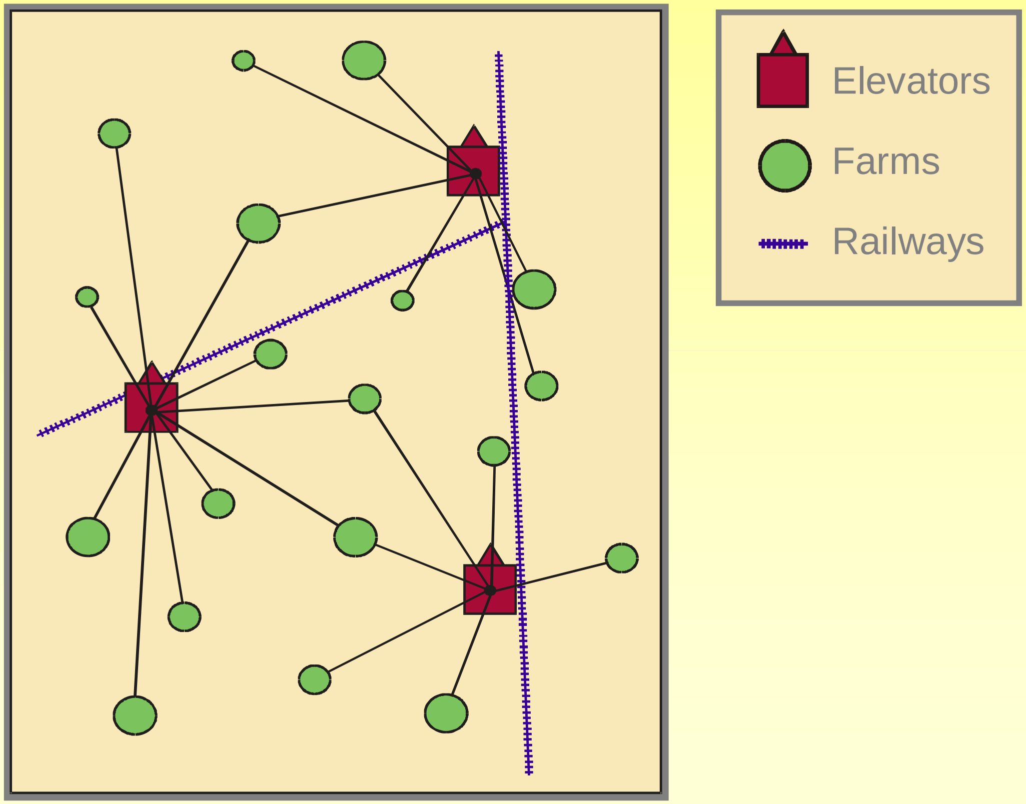
Types of Networks

- The second example is a network that includes farms and grain delivery points (Primary elevators)
- The farms would be networked with the receiving points, in this case elevators (silos), and would provide the elevators with an estimate of their holdings of the amounts of grain in storage

Networked Farms and Elevators

Fig. 1. Elevator/Farm communication network



A Modern Country Elevator in Western Canada

6-10 large bins, each of 2000-3000 tonnes

Bin Storage on a Manitoba Farm

Many bins, each up to 200 tonnes

Types of Networks

- The primary elevators would be able to call grain of the grade and protein content required to compose unit trains, which would streamline grain-handling and marketing
- The concept would call for testing grain at the farm level, which could be achieved by farmers sampling at harvest-time, and submitting samples to the elevators

Farm/Elevator Networks

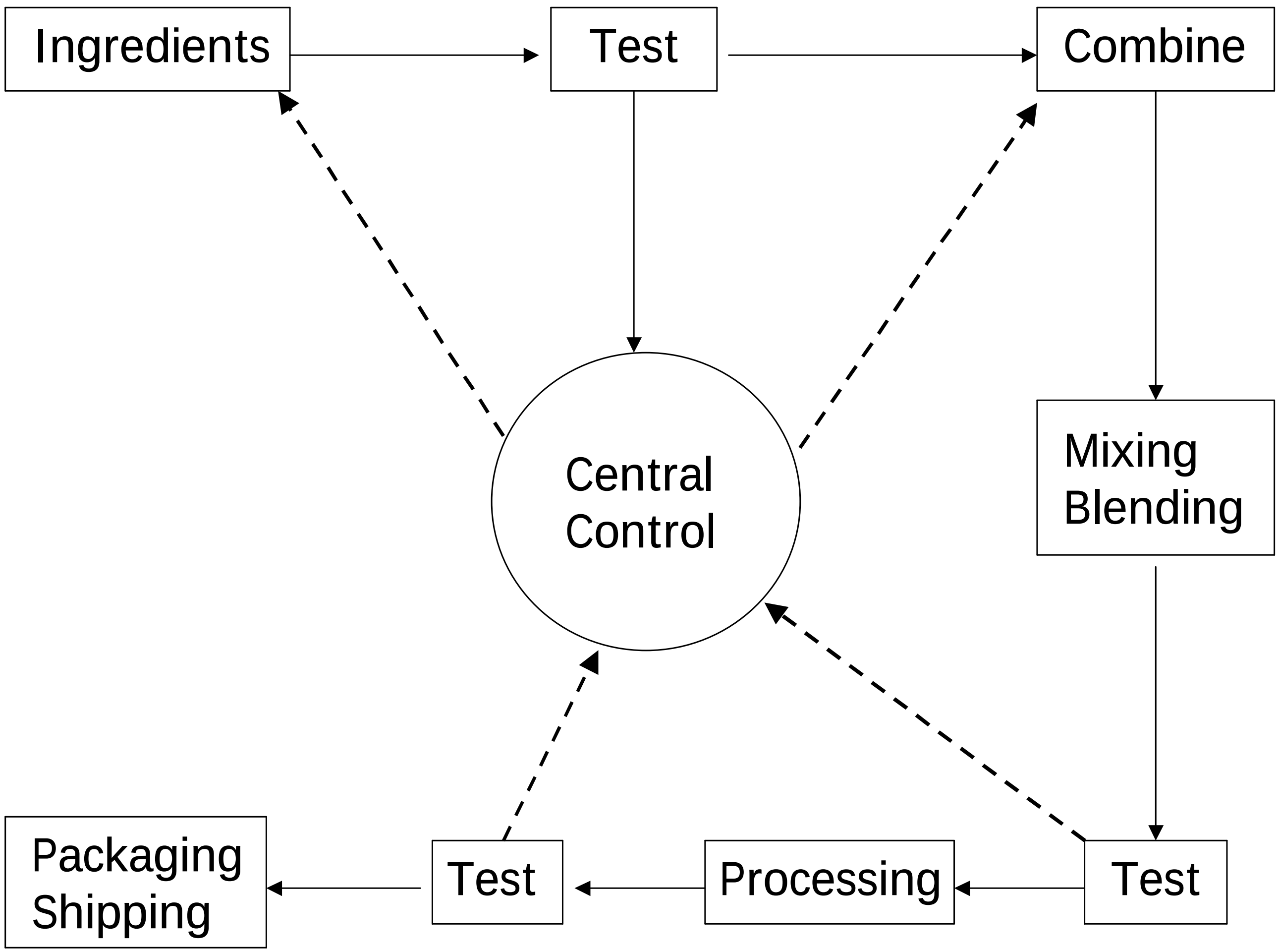
- Terminal shipping points could in turn contact primary elevators to load trains with grain of the required class and grade, thereby streamlining the entire system
- The concept would require training of farmers to collect representative samples at the time of harvest

Types of Networks

- Another type of networking is that instruments can be located at tactical points in an industrial plant
- By networking to one computer all aspects of the process can be regulated, including monitoring of the composition of raw materials, the efficiency of blending during processing, and the composition of the final products.

Typical Small Feed-mill

Process Control



Process Control

- Industrial processing plants such as flour-mills or feed-processing plants can install NIR instruments at strategic areas in the plant, and control them through a network operated from the plant control center
- Data from these instruments enable the processing plant to maintain consistent product production from the composition of raw materials to that of the finished products.
- Many of this type of network operate in the feed-and-food-processing industries.

Networking: Steps in Establishment

- The steps in establishing a NIRS network include:

1. *Determine whether a NIRS network will be of economic and/or practical benefit to the operation*
2. *Identify a person to accept responsibility for running, monitoring, and controlling the entire operation*
3. Prepare a budget for setting up the network
4. Identify control centre
5. *Identify method for networking (e.g. modem, LAN, etc.)*

Steps in Establishment

6. Identify locations for instruments (at remote locations, or at strategic locations within a processing plant)
7. Install communication system, such as a modem system, or Local Area Network (LAN) system if modems are to be used with telephones. The system can also be controlled by means of fax lines, or a wireless system
8. *Identify reference methods and reference laboratory*
9. *Determine the precision (reproducibility) of the reference methods*

Steps in Establishment

10. *Identify the instruments to be used*
11. Establish system for monitoring (e.g. frequency of check sample testing, system of sample distribution, use of on-site testing, etc.)
12. Identify source of check samples
13. *Prepare check samples*
14. Identify system for distribution of check samples
15. Identify method for correction of instrument deviations. This can be done by software such as the Foss ODIN client communication software

Steps in Establishment

16. Identify the Master instrument
17. Assure that all satellite instruments or sensing heads are functioning properly
18. Standardize all satellite instruments to Master instrument
19. Train staff in use of network software
20. Test network using limited number of locations
21. Develop and apply corrective measures to system, as necessary

Steps in Establishment

22. Verify that corrective measures have been successful
23. Extend the network to all locations
24. Test networked instruments at all locations.
25. *Prepare a detailed step-wise manual for operating the system for use in training new staff, and ensuring that all locations are using exactly the same procedures.*

Steps in Establishment

- These steps are not in order of importance.
- They are all important, but step 1 should be considered before any further action is taken
- The decision to install a network for monitoring or data access has to be taken in context with the practical and economic consequences of not doing so
- The person in charge of the network should be experienced in analytical chemistry and applied statistics. The level of responsibility is very high

Steps in Establishment

- Networking method: the modem system seems to be the most practicable for network control
- Reference methods. Most of the large-scale networks are in use in the grain industry, and are used for testing for moisture and protein contents
- It is essential to determine the precision of both reference tests

Reference Methods

- The master instrument is calibrated and monitored by the selected reference methods
- All satellite instruments are monitored through the master instrument
- The Dumas (combustion), and Kjeldahl methods are the most common for protein testing

Reference Methods

- Capacitance meters are the most widely-used reference method for moisture testing
- They are effective up to about 17% moisture content
- Above that level NIR reflectance or transmittance instruments are more reliable

The Instruments

- Monochromator-operated instruments are generally regarded as the most reliable for networking purposes
- Interferometer-operated instruments are very precise, and are also suitable for networking

Operating Software: Reference Data

- The most successful large-scale networks are operating in the grain industry
- These use artificial neural network (ANN) calibrations
- The calibrations have been based on thousands of spectra with reference data supplied (originally) to Tecator, from clients world-wide
- The spectral data have been recorded from many instruments, under many operational conditions of temperature, humidity, dust levels, and other variables

Operating Software: Reference Data

- The reference data supplied with the spectral data originate from an array of laboratories
- A range in average reference data from each laboratory is to be expected, but provided that there is no overall bias in the reference data, the range will add useful variance to the data used to compile the ANN calibrations
- The ANN calibrations for protein content have proven to be extremely stable over the last 9 years that they have been used in Canada

Monitoring: Check Samples

- A useful system is to send the satellite instruments three check samples every three months. Check samples are prepared to cover the range in protein content expected to happen under normal day-to-day operations, e.g. from about 12 to 15 % with bread wheat types
- Enough bulk check sample is prepared to send sub-samples of all of the check samples to all locations. The samples are issued with an expiry date

Monitoring: Check Samples

- Fresh sets of three samples are sent to each location a few days before the expiry date, to ensure continuity. The size of sub-samples is about 600 g, enough for most instruments
- Bulk samples are compiled at the central office of the operation, from samples sent from delivery points, such as terminal elevators, where trains are unloaded
- All protein tests of check samples are carried out on the master instrument.

Monitoring: Check Samples

- The individual samples are blended thoroughly using blending apparatus, such as a Boerner sample divider, to provide a range in protein content of low (e.g. <12.5 %), medium (12.6-14.0 %) and high (>14.1 %) in the three check samples
- These can be identified as A (low), B (medium), and C (high protein) samples
- Because the samples are of commercial origin, the overall ranges in the A, B and C check samples will be fairly consistent, but they will be freshly prepared every three months

The Last Words

- For network operations, use of comprehensive calibrations, such as ANN calibrations, in combination with modem control appears to be the most satisfactory system for instrument performance control
- **Networking is perhaps the ultimate application of near-infrared spectroscopy (NIRS)**