CERTIFICATION AND SOURCE VERIFICATION IN THE GRAIN HANDLING INDUSTRY

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ABSTRACT

Source verification (lot identity) is the ability to trace products from their initial components through a production and distribution system to an end user. Source verification is a documentation process that may also require product testing, special logistics, or other actions. Formal certification and audit is generally required. Grain markets have traditionally handled interchangeable average quality commodities. Biotechnology, safety/security concerns, and new consumer perceptions are converging to create a grain market need for source verification and the associated quality management certification systems.

Iowa State has assisted a large grain firm with the application of quality management systems, product tracing, and implementation of related statistical process controls. The grain firm has already achieved certification by an industry quality system and is moving to ISO 9000 (2000). A major goal is the ability to track product completely for individual production unit to user – a challenge for the grain firm handling bulk commodities. However, the act of creating the quality management system generated significant operating cost efficiencies applicable to its general commodity business. This presentation uses the case study of the grain elevator to illustrate the needs, actions, and challenges of introducing source verification and certification to the grain market. Data from other elevator studies is used to illustrate program costs.

Source verification and certification will change the mindset of agricultural businesses. In addition to providing security for very specialized products with restricted markets, this effort will reduce operating costs because a rigorous study of work processes is required for implementation. The conversion of commodity markets to product markets will improve profitability and efficiency of market participants. The tolerance for purity in both specialty and commodity markets will determine the actual costs associated with the programs

INTRODUCTION

Quality management systems, with their associated statistical process controls and product tracking, are not new to world industry, but the concept is a radical departure from the generic commodity mindset that has typified agriculture. Trading undifferentiated commodities at constantly eroding margins provides little incentive for quality beyond that needed for minimal acceptance. A number of powerful and wide-ranging forces are converging to create a climate of change.

- Biotechnology is creating plant and animal products with value that cannot be captured without process control from production to consumption.

- Consumers in affluent nations have increasing ability to include environmental and social values in purchasing decisions, leading to pressures on production processes as well as measurable quality of outputs.
- Precise analytical and production practices have greatly increased expectations of what should and should not be included in food. Measurements in the part per trillion range, or even of individual DNA molecules, enable near zero specifications regardless of their validity in any risk analysis.
- Fewer people are involved in direct food production which has shortened the adoption time for new technologies
- World concepts of quality assurance are in the mainstream of all markets including those of the USA. Requirements for labeling of biotech products are forcing policy decisions in retail chains.
- Reduced margins are forcing a reexamination of operating efficiencies.
- Food safety and terrorist fears have greatly increased the willingness of food marketers to implement tracking systems for security reasons.

Some attributes cannot be measured by either visual inspection (e.g., natural beef) or by chemical analysis (e.g., BST in milk). In other cases, measurement is possible but cost prohibitive. For some consumers it is the process (how it was produced or by whom) that creates value, i.e., organic, animal welfare practices, locally grown, not the grade. Process control and more importantly source verification is necessary to capture the value of the trait. Finally, increased world security concerns are causing more scrutiny of all products intended for food – either commodity or specialty.

SOURCE VERIFICATION

Source verification is the ability to trace products from their initial components (for example, from seed) through a production and distribution system to the end user. Other terms have been used for source verification – traceability, product tracking, process verification, and others. Source verification automatically applies to identity preserved products – those that are physically isolated throughout the market – but also increasingly refers to documentation in bulk commodity markets as well. Some examples of products that are or could be source verified are:

- Individual varieties grown by individual farmers (e.g., Vinton 81 soybeans)
- Specialized bulk products, such as non-GM or large seeded soybeans
- Totally contract controlled products such as health foods, organics, or pharmaceuticals (nonfood/nonfeed grains)
- General commodity grains if some risk or acceptance factor is present (for example an unapproved GM event)

Source verification is a process. Testing for specific traits and special handling are part but not all of the process. Source verification requires a documentation chain from start to finish, in addition to whatever actual confirmation testing can be done. Source verification functions even when testing is not possible, or when the value of the product is in consumer perception rather than physical attributes. As long as the integrity of the documentation is maintained, the source verification and protection will be intact.

QUALITY MANAGEMENT SYSTEMS

Source verification requires a certified (third party audited) quality management system (QMS). Quality management systems are formalized procedures for requiring discipline and reproducibility in a production process. Quality management systems force operators to document what and how processes are done, then prove though records and audit that the process, however described, is consistent. QMS do not require specific or high quality standards, just that desired standards are met. QMS are also a convenient framework under which to introduce environmental and/or safety standards.

The worldwide framework for quality management systems has been the ISO 9000 series of standards. Many manufacturing industries have customized a “front end” for the ISO standards to make them more user friendly for specific situations. This is also happening in agriculture, as in for example the American Institute of Baking Quality Systems Evaluation (QSE) program for flourmills and bakeries. Custom programs can also incorporate other elements such as food safety or environmental protection not addressed by ISO 9000.

All successful quality management systems incorporate the eight guiding principles of ISO.

1. Customer focus
2. Leadership
3. Involvement of people
4. Process approach
5. System approach to management
6. Continual improvement
7. Factual approach to decision making
8. Mutually beneficial supplier relationships

For the producer and the user alike, quality management systems have immediate benefits:

- Operating efficiency and cost savings are created through the detailed study of operations required for QMS. Industrial firms have averaged around $1.50 - $2.00 of cost/efficiency gains for every $1 invested.
- The chain-of-custody documentation that is required for a comprehensive QMS will be a major benefit in marketing sensitive or narrowly focused products, such as genetically transformed pharmaceutical/industrial grains, or specifically fed specialty animals. Some of these products create genuine concerns to general users, and often are very hard to test/validate in the traditional inspect-and-pay scheme of commodity markets.
- Exhaustive documentation and procedural controls are well suited to control of security threats, such as addition of toxic agents or production limiting diseases. For example, white mineral oil is applied for dust control to nearly all grain handled at elevators, and the number of suppliers is very limited. The stringent validation and audit requirements

of a QMS, which normally are imposed on suppliers to QMS firms, greatly reduce the chance that a terror agent could be distributed in this way.

For users, buying from QMS-certified producers/handlers is an automatic method of predelivery tracking. The producer and first handler must be involved in source verification if any meaningful tracking and/or quality improvements are to be made. Source verification and audited quality management systems are opening direct market channels that require openness and transparency.

There are two routes by which QMS are being introduced to grain production – through normal grain markets and through producer-held companies created to develop markets and coordinate very specialized production. The next discussion is a case study of the normal grain market application.

GRAIN INDUSTRY CASE STUDY

Background

Several grain companies are developing internal quality management systems. There are examples of ISO certification – Colusa Elevator Company, Consolidated Grain and Barge, Inc., and of other systems such as AIB QSE – Farmers Cooperative Elevator Company, Farmland Industries; InnovaSure-Cargill Inc.

Firms that have an audited quality management system are good candidates for direct marketing arrangements – producer to end user. Transportation and logistics have often prevented direct sales of bulk products; the firms creating source verification are becoming large enough that coordination of source verified bulk shipments is much more feasible than in the past.

In this case study, Farmers Cooperative Company (www.fccoop.com), Farnhamville, Iowa, divided source verification into nine general areas, and specific procedures/controls were created for each. This is the organization of Quality Systems Evaluation, American Institute of Baking, Manhattan, Kansas (www.aibonline.org).

- Raw Materials
- Process Control
- Process Verification (Statistics)
- Finished Product Acceptability
- Storage and Shipping
- Instrument Accuracy and Calibration
- Personnel Training
- Plant Programs (Safety, etc.)
- Quality Policies (Management Commitment)

FC initially began the quality management system as a means to create more marketing opportunities for the company's grain department. The initial objective was to have a universally recognized quality system in place, so that as end users sought Identity Preserved (IP) grain origination, FC could present a program that would have immediately recognizable credibility to potential partners. This objective changed through the process.

Initially, the ISO 9000 system was selected as the quality system to be adopted. More than a year was spent unsuccessfully attempting to learn and adapt FC's grain business to the ISO system. While ISO works quite well for a manufacturing environment attuned to its terminology and organization, it was difficult to adapt directly to the personnel and operation of a grain elevator.

The AIB system was chosen because it met the initial criteria for a certified quality system. Primary points included:

- Established credibility
- 3rd party auditing
- Global recognition (particularly in Europe, the Mideast, Mexico, and Japan)

AIB provided an added advantage in that the QSE system, and the personnel who represent it, were acclimated and responsive to the nature of what happens in the grain business. Once the experience and benefit of AIB certification was clear, the commitment was then made to reorganize the AIB system to ISO 9000 (2000), with registration expected in 2003.

Implementation

Elevator operations were described in flowcharts such as in Figure 1. Flow charts identify operations needing specified work procedures, statistical control, or both.

All documentation was placed in standard formats with stated dates for review and implementation. Work procedures were written with the objective of being training tools as well as documentation. Figure 2 shows an example procedure and Table 1 gives a portion of the overall procedure listing with associated review dates/accountability. Every element of elevator operations was assessed, documented, and assigned to one of the nine areas.

Statistical process control was introduced in situations where control charts could be used as ongoing performance measures. A good example is the grain analysis operation, both inbound and outbound. The goal was established to make FC's house grades (company-operated testing) as accurate as testing done by Official USDA inspectors.

Table 2 shows the tolerance schedule established to meet the goal. Periodic regular comparison to Official inspections is used as the monitoring tool and control charts are used to demonstrate progress. Figures 3 and 4 show control chart examples. Employees regularly review these charts and identify sources of error.

The control charts can be used in several ways:

1. Evaluating accuracy of inbound grades and inventory records. The goal is to have no more than 5% data points outside the tolerance values. This also creates much more accurate inventories from which to base blending and merchandising decisions.

2. Operator training. The standard work procedure for this data requires review of out of tolerance situations to see if there are problems that could be fixed. For example, the test weight data (Fig. 3) indicate a systematic bias that presumably could be removed. If the average bias (0.4 lb/bu) is removed, then the number of data points outside tolerance falls to less than 5%.
3. Reconfiguration of regulatory requirements. A regular control chart, traceable to national references, is a much more robust verification of accuracy than point-in-time regulatory inspections.

Organized statistical analysis of measuring systems also identifies corrective actions that will yield maximum benefits. For example, accurate physical measurement of inventory is important for management. Table 3 shows an error analysis of the bin inventory process; the largest error component was test weight measurement.

<u>Benefits Experienced So Far</u>

The value of a quality system can be realized without ever developing a new market or participating in "added value" opportunity. Undoubtedly, there is expense in developing a quality system and at this point, the system is not complete. Even without having the system fully completed, the company is benefiting from improved operations. Some examples include:

Training

QSE specifically calls for Job Descriptions and Work Procedures. The documents form the essence of a thorough training program. The Job Descriptions establish the specific Job Tasks for which the employee needs to be trained. The Work Procedures provide the outline for the training. Employees and Supervisors sign off on the Work Procedure, confirming that both agree that the employee is not only qualified to perform the work, but also authorized and responsible for taking corrective action.

Documentation

Less is taken for granted, ignored, or overlooked. Documentation assures the systematic follow through of functions such as: proper handling of mineral oil and fumigant; periodic equipment calibration; pest control program monitoring; quality self-inspection program; and other routine yet critical activities.

Statistical Performance Evaluation

Grading is a primary function of any commodity grain business and a function that can easily be taken for granted. FC has implemented a system that randomly selects 4% of inbound truck grades and compares the grades with an official grade on the same sample. A similar system is in place for all outbound rail grades. This serves the dual function of monitoring the performance of FC grading personnel while providing a third-party evaluation for end users.

Programmed Corrective Action

Employees understand at what point they are expected and authorized to make changes. This becomes a natural response because of components of the system:

- Effective job descriptions

- Training
- Definition of authority
- Statistical performance information continually being provided to the employees

Inventory Information
One of the fundamental premises of FC's Quality System has been to "follow the grain." Because of this objective, MIS systems have been upgraded to allow tracking of inbound truck scale ticket numbers through the elevator bins. The FC MIS system is receiving significant refinement so that we will be able to track the grain through our elevator from the receiving pit, through storage and onto the outbound railcar. An immediate benefit of this system is the improved precision of inventory management and refinements in the process of targeting loadout grade specifications.

Employee Confidence and Professionalism
A common problem in the grain industry seems to be attracting employees to work in the grain business and retaining experienced employees. With improved training systems and extended levels of responsibility and authority, better performance has been observed. Career development is more easily visualized and measured leading to improved job satisfaction.

Food Grade Mindset
A significant change in thought process has evolved as the result of employee involvement in quality system development. The philosophy of handling grain as a food ingredient affects how employees do their job. More consideration is given to the details of work.

The benefits gained by adopting a Quality System will only be realized if accepted by those employees who are responsible for using the process. It could be argued that development could have been streamlined if it was the focused effort of one or two individuals. It is important to remain focused that the goal is to implement and use the system, not just to develop it. Company employee participation in development was not limited. A sampling of some of the positions involved in the quality system development include:

- General Manager
- Grain Department Manager
- Regional Grain Superintendent
- Elevator Superintendent
- Location Manager
- Elevator Operator
- Railcar Mover Operator
- Truck Scale, Sampling, & Grading Operator
- Grain Accounting Manager
- Grain Clerk
- MIS Department Manager
- Computer Programmer

A conservative annual cost-benefit analysis was done for the test facility. Table 4 summarizes documented benefits versus expected average costs of maintaining the system. The 2:1 ratio is above manufacturer industry norms for QMS.

REGULATORY PARTICIPATION

QMS are not regulatory. However, certain regulation is unavoidable to protect public health and set business standards, which mean QMS can be the agent of action, especially as more complex products are introduced.

Products of biotechnology are no different than any other new compound proposed for introduction or regulation in the food chain. The function of regulation is the same – to identify risks and establish levels below which risk is deemed insignificant. Regulation cannot and should not set consumer preferences, nor should it be constructed to facilitate one set of preferences over another.

For example, there is a regulatory tolerance for aflatoxin (a potent carcinogen) in peanut products – peanut butter for example. Peanut butter can be sold if it meets the tolerance, even if the aflatoxin level is not zero (which it rarely is). If a consumer group wants zero aflatoxin peanut butter, then it will have to pay a cost for going beyond the scientific consensus of what is generally safe.

This principle has already been applied to several of the agronomic biotech products, in that they have full and interchangeable approval with non-biotech grains (100% tolerance). However, there are customer groups that are purchasing with limits on these grains. Grains with modified output traits, either food/feed modifications or nonfood/nonfeed modifications are no different.

It is not the function of the regulatory system to go beyond protection of the public safety. Tighter limits than those required for protection are a market function. If consumers desiring more limits are willing to pay for their requests, most certainly some seller will grant those requests.

Regulatory agencies must avoid creating QMS other than those recognized by industry at large. Conversion of formats and reorganization of documentation is time-consuming and expensive. Audit and verification to standard formats are more valuable services than direct regulatory intervention.

Costs

Isolation systems with related QMS will create costs for grain handlers. As demonstrated in the case study, the QMS itself can create profits even to the commodity business. These profits can either be retained or allocated against the costs of physical testing/handling operations related to an IP program.

The costs of IP programs will be determined on a case-by-case basis. If the IP product is unapproved or unacceptable in the commodity market, then costs are incurred in both the commodity and IP program. This would be the example of StarLink or nonfood/nonfeed grains. Fully acceptable IP products create costs only to the IP program. This is illustrated conceptually in Figure 5.

The allowable limit (tolerance) of the specialty product in commodity is the key variable. If the tolerance is large or 100% (fully accepted), then only the testing and handling costs to meet customer requirements are incurred in the IP program. The smaller the tolerance (down to zero), the greater the effort will be to maintain perfect isolation. Low tolerance products are likely to be high value and more complex to test, so probably (but not necessarily) the basic cost of the IP program will be higher as well.

For one case of a fully interchangeable high value product (high oil and protein soybeans) representing 33% of receipts, Table 4 gives some observed cost data. These were collected at grain elevators in three Iowa counties. The protein and oil test is simple and the consequences of misclassification are only the loss in value of the specialty beans.

This study demonstrated that elevator size was not a key determinant of cost. Larger elevators were just as able to be in the low cost group as smaller ones. Approximately half the elevators, representing 75% of storage capacity in these counties, would likely be able to make this simple segregation for less than 3 cents per bushel additional cost.
For other situations, as the proportion of specialty to commodity grain decreases, and the complexity of the quality traits increases, these base costs certainly would rise.

SUMMARY

Source verification (lot identity) is the ability to trace products from their initial components through a production and distribution system to an end user. Source verification is a documentation process that may also require product testing, special logistics, or other actions. Formal certification and audit is generally required. Grain markets have traditionally handled interchangeable average quality commodities. Biotechnology, safety/security concerns, and new consumer perceptions are converging to create a grain market need for source verification and the associated quality management certification systems.

Iowa State has assisted a large grain firm and a producer-operated production network with application of quality management systems, product tracing, and implementation of related statistical process controls. Both organizations are approaching ISO 9000 certification; the grain firm has already achieved certification by an industry quality system. A major goal is the ability to track product completely for individual production unit to user – a challenge for the grain firm handling bulk commodities. However, the act of creating the quality management system generated significant operating cost efficiencies applicable to its general commodity business. This presentation uses the case study of the grain elevator to illustrate the needs, actions, and challenges of introducing source verification and certification to the grain market. Data from other elevator studies is used to illustrate program costs.

Source verification and certification will change the mindset of agricultural businesses. In addition to providing security for very specialized products, such as pharmaceutical grains, this effort will reduce operating costs because a rigorous study of work processes is required for implementation. The conversion of commodity markets to product markets will improve profitability and efficiency of market participants. The tolerance for purity in both specialty and commodity markets will determine the actual costs associated with the programs.

Figure 1.

Elevator Receiving Flow Chart

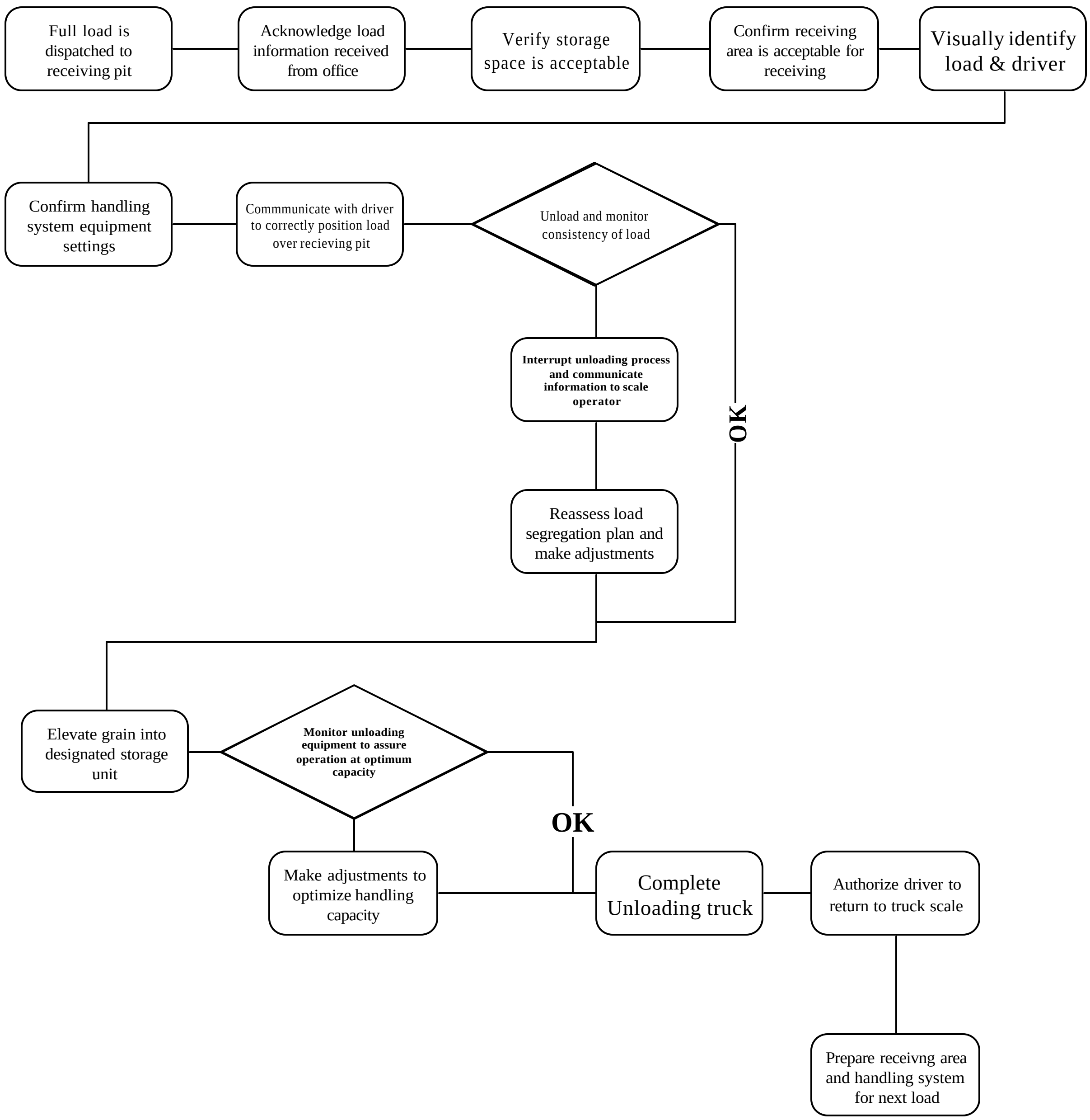


Figure 2. QMS Work Procedure Example

U:\Shared\Farnhamville QC data\Procedures\Approved\AIB 2.03, Inbound Probing & Sampling Procedure.doc
Original Version: 8-9-94, Last Revision: 01-23-02; By: TS Next Scheduled Review: 09-01-03
AIB Reference Section(s): 2.03 (2000); 2.03 (2002) ISO 9000-2000: 8.02.3, 4.02.3

Farmers Cooperative Company
Odebolt, Iowa

PROCEDURE: Probing and Sampling Inbound or Outbound Loads

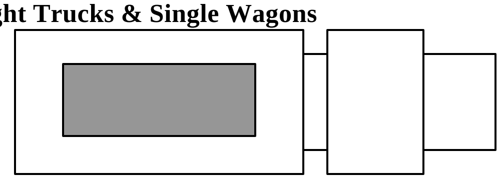
Background: Samples are taken on all inbound and outbound trucks and wagons using a mechanical truck probe. It is critical that the sample collected be representative of the load from which it is taken. Following established patterns and methods assures that the sample will be representative.

Objective: The truck probe will be operated using methods that assure collecting a sample that is representative of the contents of the load.

Procedure for Probing and Sampling Inbound and Outbound Loads:

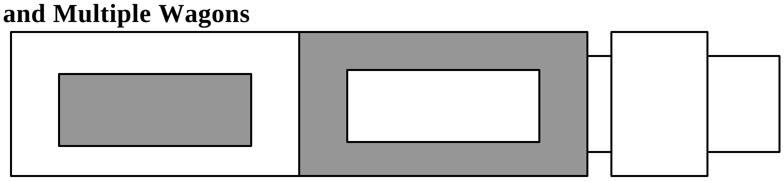
1. Collect samples from each hopper (if vehicle has multiple hoppers).
2. Take a minimum of two probes per vehicle:
    a. One probe near center of load.
    b. One probe no further than 2 feet from outside box.
3. **Insert the full length of the probe into the grain, or as much of the probe as box depth allows.**
4. Accumulate a minimum of 500 grams of representative grain for grading.

Straight Trucks & Single Wagons



One probe inside shaded area & 1 probe outside shaded area

Semis and Multiple Wagons

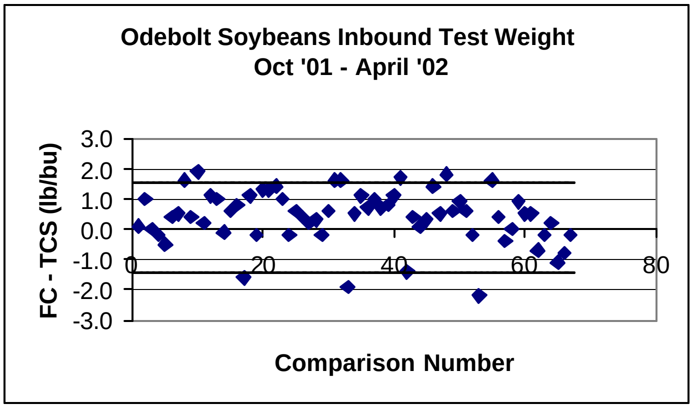


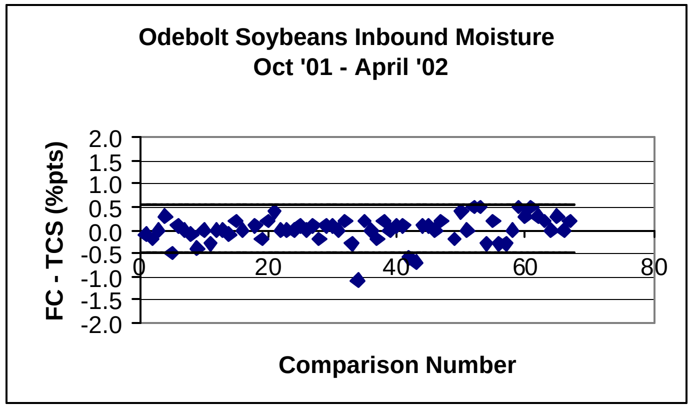
One probe from each of the shaded areas

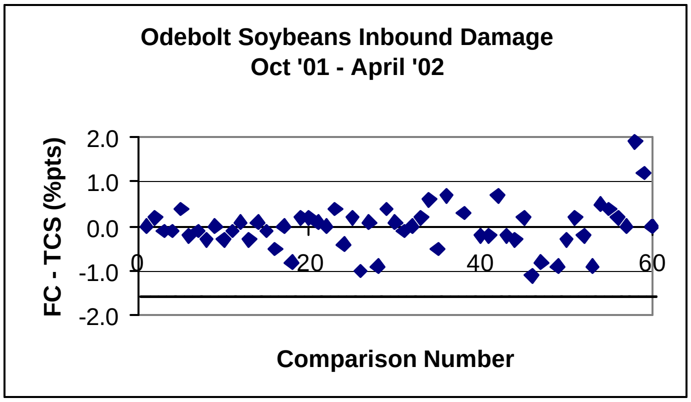
Corrective Action:
In the event of mixed grain in collection hopper, moisture in probe tube, probe malfunction, too small of a load, or evidence of spiking, sample load at pit or hand probe.

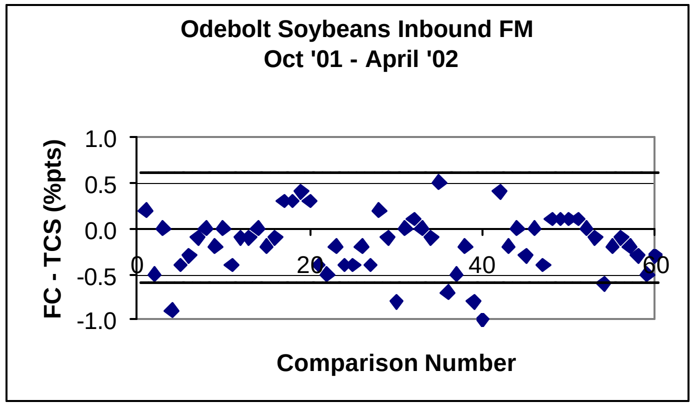
EMPLOYEE TRAINING RECORD:
Training Approved and Authorized:______________________________Date:_________
Employee Signature:____Date:_________

Figure 3. Example of Control Charts for Grading Inbound Soybeans at a Country Elevator









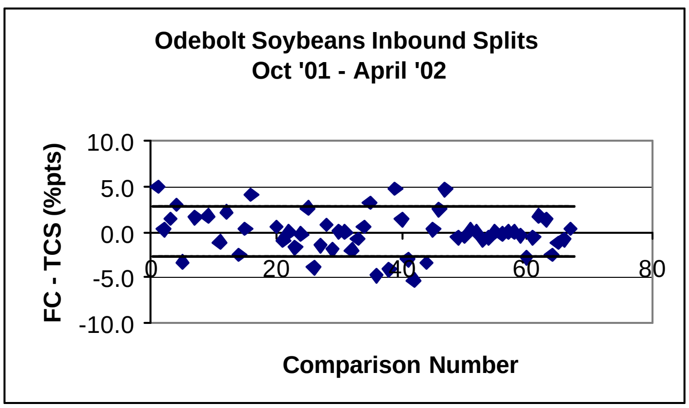
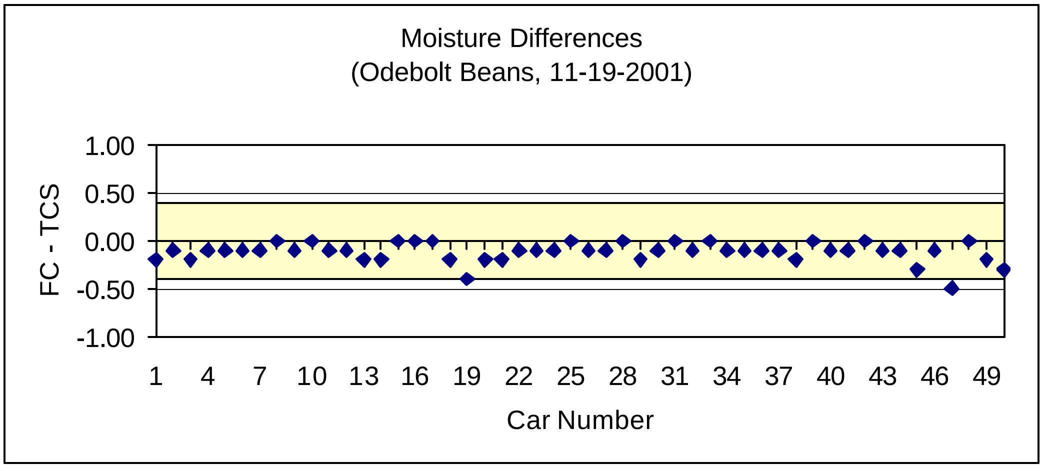
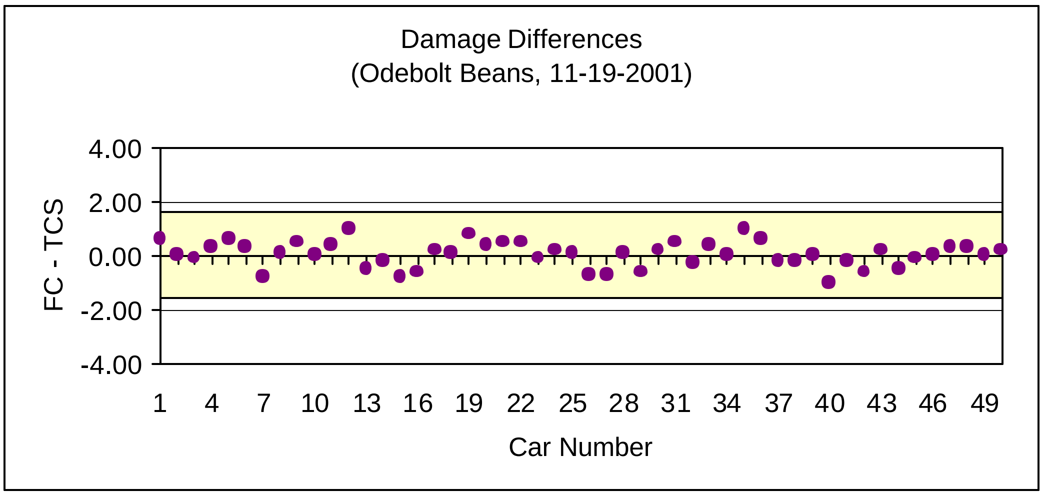


Figure 4. Example of Control Charts for Rail Soybean Grades





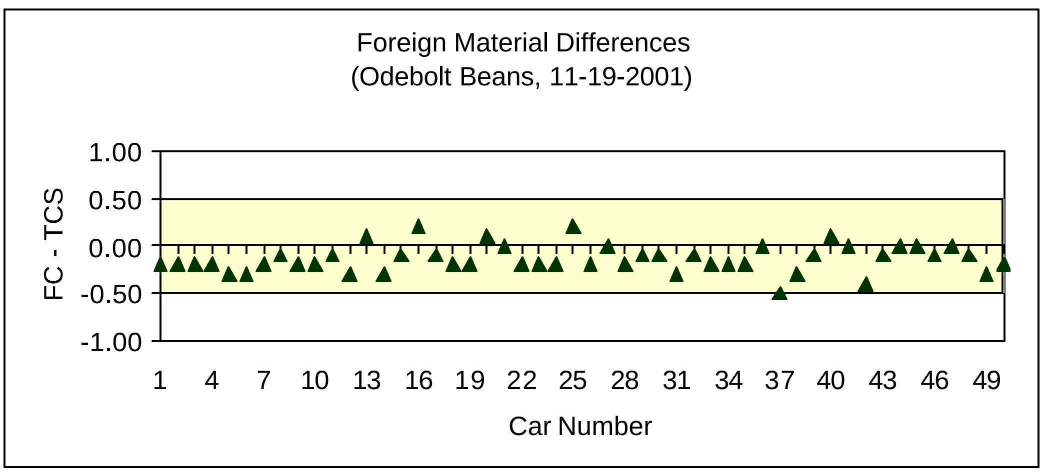


Figure 5. Costs of Isolation/Segregation to IP and Commodity Programs

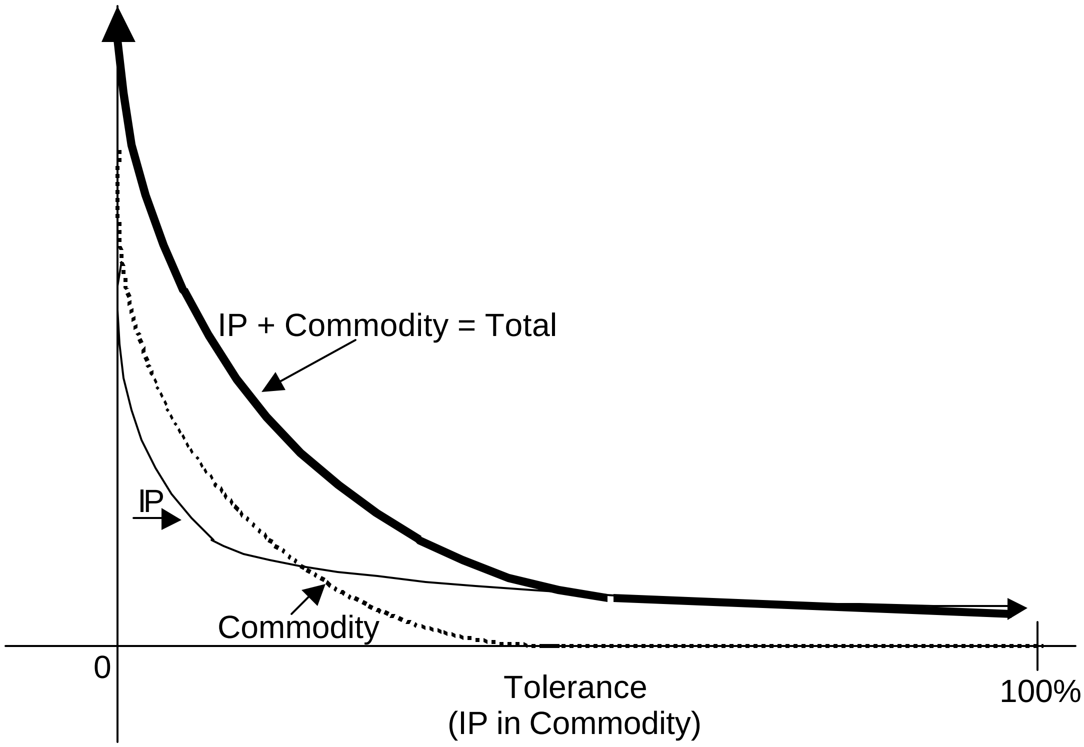


Table 1. Example of Procedure Listing for Grain Elevator QMS

AIB Section # (Old # System)	Topic	Current Version Date	To Be Evaluated for Revision
	Effective Date:		11/11/03
1.01	Procedure for Receiving Bulk Mineral Oil	07/26/02	12/01/03
1.06	Procedure for Receiving Phosphine Pellets	06/05/02	07/01/03
1.12	Mineral Oil Storage Requirements Policy	08/13/02	12/01/03
1.15	Grading Procedure, Inbound Corn	01/23/02	09/01/03
1.15	Grading Procedure, Inbound Soybeans	01/23/02	09/01/03
1.15	Inbound Probing & Sampling Procedure	01/23/02	09/01/03
1.18	Raw Material Supplier Approval-Removal Procedure	09/09/02	12/01/03
1.19	Procedure Rejecting Contaminated Grain Deliveries	02/14/02	05/01/03
2.01	Trackmobile Assignment & Accountability Policy	10/22/02	06/01/03
2.01	Trackmobile Inspection Procedure	09/16/02	06/01/03
2.01	Trackmobile Use & Maintenance Policy	10/22/02	06/01/03
2.03	Grain Temperature Control Procedure	01/30/02	01/01/03
2.03	Grain Temperature Monitoring & Recording Procedure	03/22/02	01/01/03
2.03	Infested Grain, Identification & Management	03/21/02	01/01/03
2.04	Start-up and Change Over Procedure, Commodity Corn & Soybeans	07/16/02	04/01/03
2.06	Grain Inventory Physical Measurement, Flat Storage Structures	08/27/02	08/01/03
2.06	Grain Inventory Physical Measurement, Large Diameter Bins	08/27/02	08/01/03
2.06	Grain Inventory Physical Measurement, Standard Grain Facility	08/27/02	08/01/03

Table 2. Tolerances for Farmers Coop Quality Control Program

Test	Program	Reference	Std. Dev.	Tolerance, by number of observations included in average					GIPSA Std. Dev.
				1	5	10	25	100	
Moisture (corn)	Inbound trucks	TCS	0.30	0.60	0.27	0.19	*0.15*	*0.15*	
	Outbound trucks	Destination	0.30	0.60	0.27	0.19	*0.15*	*0.15*	
	Outbound rail	TCS	0.25	0.50	0.22	0.16	0.10	*0.10*	0.25
Moisture (soybeans)	Inbound trucks	TCS	0.25	0.50	0.22	0.16	0.10	*0.10*	
	Outbound trucks	Destination	0.25	0.50	0.22	0.16	0.10	*0.10*	
	Outbound rail	TCS	0.20	0.40	0.18	0.13	*0.10*	*0.10*	0.18
Test Weight	Inbound trucks	TCS	0.75	1.50	0.67	0.47	0.30	*0.30*	n/a
(GAC2100)	Outbound trucks	Destination	0.75	1.50	0.67	0.47	0.30	*0.30*	n/a
(cn, sb)	Outbound rail	TCS	0.50	1.00	0.45	0.32	0.20	*0.20*	n/a
Test Weight	Inbound trucks	TCS	0.50	1.00	0.45	0.32	0.20	*0.20*	
(cup)	Outbound trucks	Destination	0.50	1.00	0.45	0.32	0.20	*0.20*	
(cn, sb)	Outbound rail	TCS	0.40	0.80	0.36	0.25	0.16	*0.10*	0.25
FM (cn, sb)	Inbound trucks	TCS	0.30	0.60	0.27	*0.20*	*0.20*	*0.20*	
	Outbound trucks	Destination	0.30	0.60	0.27	*0.20*	*0.20*	*0.20*	
	Outbound rail	TCS	0.25	0.50	0.22	*0.20*	*0.20*	*0.20*	0.18
Damage (cn, sb)	Inbound trucks	TCS	0.80	1.60	0.72	0.51	0.32	*0.30*	
	Outbound trucks	Destination	1.00	2.00	0.89	0.63	0.40	*0.30*	
	Outbound rail	TCS	0.80	1.60	0.72	0.51	0.32	*0.30*	0.80
Splits (sb)	Inbound trucks	TCS	1.40	2.80	1.25	0.89	0.56	*0.50*	
	Outbound trucks	Destination	1.70	3.40	1.52	1.08	0.68	*0.50*	
	Outbound rail	TCS	1.40	2.80	1.25	0.89	0.56	*0.50*	1.40
NIR Protein (soybeans)	Inbound trucks	TCS	0.40	0.80	0.36	0.25	*0.20*	*0.20*	
	Outbound trucks	Destination	0.40	0.80	0.36	0.25	*0.20*	*0.20*	
	Outbound rail	TCS	0.30	0.60	0.27	0.19	0.12	*0.10*	0.30
NIR Oil (soybeans)	Inbound trucks	TCS	0.40	0.80	0.36	0.25	*0.20*	*0.20*	
	Outbound trucks	Destination	0.40	0.80	0.36	0.25	*0.20*	*0.20*	
	Outbound rail	TCS	0.30	0.60	0.27	0.19	0.12	*0.10*	0.30
NIR Oil (corn)	Inbound trucks	TCS	0.30	0.60	0.27	*0.20*	*0.20*	*0.20*	
	Outbound trucks	Destination	0.30	0.60	0.27	*0.20*	*0.20*	*0.20*	
	Outbound rail	TCS	0.20	0.40	0.18	0.13	*0.10*	*0.10*	0.20

Note: Numbers in italics were fixed at an estimated practical level, higher than theoretical limit.
Note: GIPSA estimates of standard deviation taken from CuSum inspection plan.
Note: TCS is the official grain inspection agency serving FC.

Table 3. Error Analysis for Volumetric Measurement of Grain Quantity

Source of Error	Estimated Maximum (± 2SD)	Squared Error
Stretch of tape (± 1 in/50 ft)	0.2%	0.04
Level fill depth estimation (± 6 in/50 ft)	1.0%	1.00
Average test weight (± 1 lb/bu)	2.0%	4.00
Moisture (± 1% M)	1.2%	1.44
Pack factor	1.0%	1.00
		7.48
Estimated maximum overall error	2.7% (= $(7.48)^{1/2}$)	
Source: Farmers Cooperative Elevator Co., Farnhamville, Iowa		

Table 4. Annual Cost-Benefit Summary for Quality Management System at One Elevator.

Operation	Cost Savings
Grading	$1,085
Inventory Control	10,675
Operations Efficiency	2,180
Regulatory Compliance	5,300
Employee Development	3,400
Total	$22,640
Cost of QMS	$11,250
Ratio:	2:1
Source: Farmers Cooperative Elevator Co., Farnhamville, Iowa	

Table 5. Grain Segregation Costs and Operating Parameters for Elevators in Three Iowa Counties

	Estimated costs per bushel (cents)			
	1.0 – 1.9	2.0 – 2.9	3.0 – 3.9	4.0 and up
Rail elevators	3	9	4	1
Truck only elevators	2	11	14	6
Totals	5	20	18	7
Average storage (million bu) (range)	3.70 (0.9 – 6.8)	1.51 (0.8 – 4.0)	0.63 (0.4 – 1.0)	0.35 (0.1 – 0.5)
Percent of total capacity	28	50	19	3
Number of pits/elevator (range)	5.2 (4 – 7)	2.9 (1 – 3)	2.1 (1 – 3)	1.4 (1 – 2)
Average elevation capacity per pit (bu/hr) (range)	11,200 (4,500 – 20,000)	10,200 (5,700 – 15,000)	5,400 (3,000 – 10,000)	3,900 (3,000 – 5,000)

Calhoun, Webster, and Marshall counties; 1994 data
Costs based on testing all inbound grain with a near-infrared analyzer, and physical segregation of 33% as higher value