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Analysis Of Process And Troubleshooting Work Behavior

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The time was that an employee worked his way up in an organization and learned the ropes from those that knew the ropes. Knowing the ropes was largely dependent upon being a reasonably alert person with a reasonably positive attitude toward employment in the company and having a great deal of experience. With these characteristics, old-timers could report with great authority on the idiosyncracies of company process, equipment, and tools that regularly affected their working lives.

This serene model of the work-place has drastically changed. To deny this is to deny the contemporary nature of industry and business. Times have changed. Today's production and maintenance personnel are as apt to have a white shirt and stethoscope as coveralls, an oil can, and an assortment of mechanic's tools. Furthermore, machine operators may be as adept at computer programming as in cutting tool selection. The presence of automated and cybernetic production systems erase old stereotypes of how work gets done. And, costly equipment decreases the possibilities of having backup equipment while it increases the pressures of keeping the equipment running so as to obtain a return on such an enormous capital investment. Electronic technology, the heart of process control, changes at such a high frequency that equipment can become obsolete at an alarming rate. These developments reach back to increase the pressures of obtaining a fair return on capital investment required in the industrial sector.

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What has happened is that work systems, and the nature of work itself, have drastically altered in the past twenty years. A very fundamental problem has arisen as a result of these changes. The basic problem is that of keeping industry and business running—keeping the systems up and running, if you will. The consequences of not doing so are monumental. They can be characterized by enormous financial loss (Petzinger, 1980) and, in the case of national defense—death and destruction (Fallows, 1981).

The resulting issue is that people need to *learn the ropes* more efficiently and effectively than they have in the past. Additionally, one can see figuratively that the ropes may not be ropes at all—they may be cables—or even laser beams.

The present trend in industry and business, moving from unstructured training to structured training, is in recognition of these changes (Swanson & Murphy, 1981). And, in most instances one can view within structured training the commitment to rigorous analysis of work behavior as a basis for training programs. Difficulty arises in the inherent limitations of work behavior analysis methods that are generally used by trainers of skilled and technical workers. The major thesis presented herein is that the standard job and task analysis techniques used by trainers are inadequate in isolating and describing many of the critical behaviors required of today's technical workforce.

The Problem

The problem was the need for an analysis method that would focus on work behaviors required to keep systems running. Additionally, this method would have to be both powerful and simple. Powerful in the sense that it truly would get at the troubleshooting work behaviors required of a job and simple in the sense that the analysis method would be reasonably easy for trainers to learn and to use in the course of their work.

The major output of traditional job and task analysis is essentially procedural knowledge . . . cook-book or step-by-step information. Using the job and task analysis method while relying on a subject matter expert, an analyst can efficiently and effectively ferret out the detailed information needed to operate a piece of equipment under normal conditions. If abnormal conditions arise, the knowledge needed to respond is often left to the worker's resourcefulness plus his/her on-the-job experience. One can learn to operate a system from a procedural perspective in training without ever knowing what is really going on inside the system. Trained workers may not even understand the process(es) involved, let alone know how to diagnose an inoperable or failing system. Therein lies the difficulty, because diagnosing or troubleshooting inoperable or failing systems is one of the critical tasks required to keep industry and business running.

As one views the strengths and limitations of procedural knowledge, a realization emerges that process and troubleshooting knowledge should also be analyzed. In the case of a simple flashlight, one could view the system and come to the statement that removing the battery will result in no light. This is process knowledge and in essence is a forward analysis method. Given a flashlight that does not work requires troubleshooting knowledge, which is based on backward analysis, or the diagnosis of a failed system. The battery may be missing, the bulb burnt out, and possibly a dozen other options. Where does one start? Again, information other than procedural information or process knowledge is required to troubleshoot a system efficiently.

In more specific terms, the problem under investigation and reported here within was the development and refinement of a simple and powerful method to analyze process knowledge and the troubleshooting work behavior.

Process and Troubleshooting Method

Processs and troubleshooting analysis is viewed as one of three techniques constituting a complete repertoire of work analysis methods useful to trainers. The other two methods include work analysis and subject matter analysis (Swanson, 1979, 1981; Swanson & Sisson, 1980). The development of a process and troubleshooting analysis method was a response to real employee performance problems which are alluded to regularly in the literature. The classic work titled *The Human Operator in Process Control,* edited by Elwyn Edwards and Frank P. Lees (1974), provides a comprehensive theoretical construct for process and troubleshooting analysis.

The components and their order in the process and troubleshooting model that is presented were born out of experience and logic. The graphic presentation of the model is presented in Figure 1. Within it the general system flow component provides a holistic view of the system being worked upon while the equipment parts and purposes provides more microscopic information. Process analysis and, more critically, troubleshooting analysis provides the important blend of whole-part knowledge that is necessary to proficiently monitor system processes or to troubleshoot systems in the workplace.

A closer view of the process and troubleshooting analysis steps, their purposes, and the techniques used follows. These include system flow, parts and purposes analysis, process analysis, and troubleshooting analysis.

System Flow

The system flow results in breaking a process into its components and traces the materials from input to output through the system. A worksheet and standard flowchart symbols are used to aid in graphically portraying the system. In that most systems are made of several sub-systems (eg. electrical, pneumatic, and mechanical), it is best to begin with the spine of

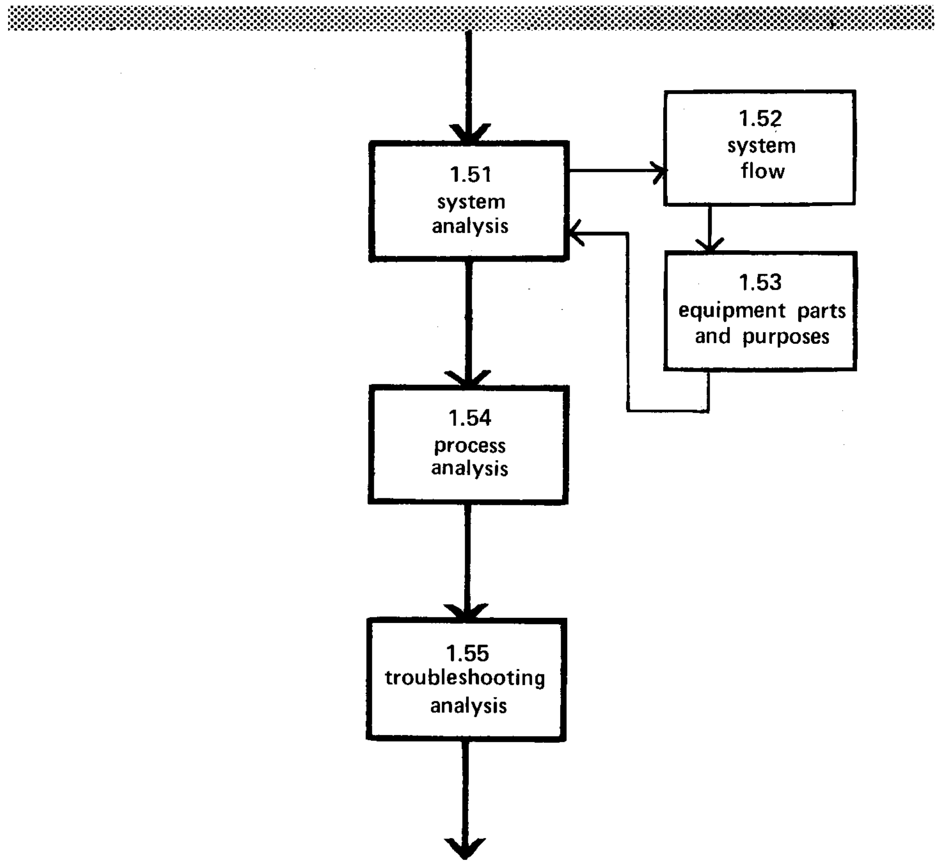

Figure 1. Process & Troubleshooting Analysis

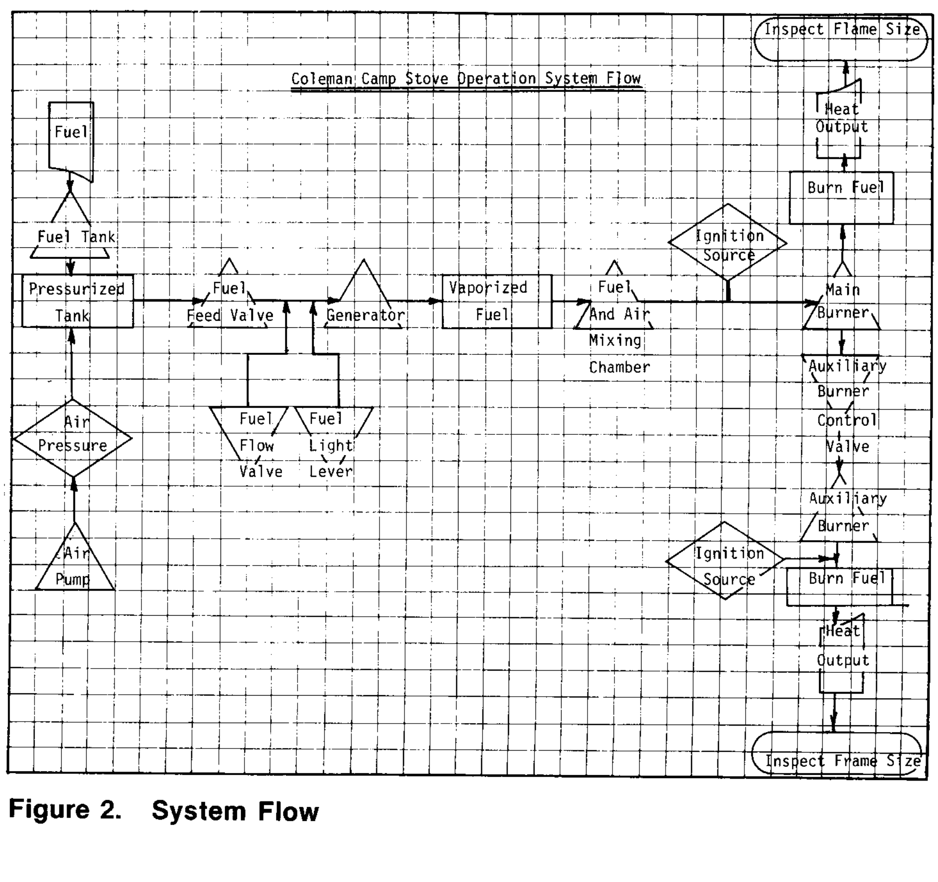

Figure 2. System Flow

PART USE CORRECT NOMENCLATURE	PURPOSES EXPLAIN WHAT THE PART DOES. ALSO EXPLAIN HOW IT WORKS. IF NOT OBVIOUS.
1. Main housing and cover	-Contains burners, grate, generator, and all other parts of stove
2. Wind baffles	-Side shields attached to housing cover. Protect burners from wind and side draft.
3. Fuel tank	-Stores fuel for burners. Sealed unit that can be pressurized
A. Pump cylinder	A. Built in tube or cylinder that houses air pump
B. Fuel inlet	B. Access for fuel filling
4. Fuel cap	-Covers fuel inlet hole in fuel tank. Has rubber seal to prevent air leaks from pressurized fuel tank
5. Air pump unit	-Unit attached to fuel tank. Used to pump air into fuel tank to pressurize fuel
A. Pump leather	A. Acts as piston to pump air into fuel tank
B. Pump plunger	B. Attached to pump leather. Provides operator lever to operate pump leather with
6. Fuel feed valve	-Valve that feeds fuel from fuel tank to generator unit - installed in top of fuel tank
7. Fuel flow valve wheel	-Controls amount of fuel going from fuel tank through fuel feed valve to generator. Hand controlled wheel or know
8. Fuel generator	-Changes liquid fuel from fuel tank to vaporized fuel that enters fuel and air mixing chamber
9. Fuel and air mixing chamber	-Receives vaporized fuel from generator. Mixes fuel and air in proper proportion for best burning and feeds to main burner unit
10. Burners - main and auxiliary	-Distribute fuel into circular pattern for ignition and burning
11. Fuel lighting lever	-Two position valve. When in "up" position, allows flame to be lit and burn until air is purged out of tank, generator, and burners. after air is purged from system (about one minute) lever is turned "down" to allow full fuel flow if operator desires it.
12. Auxiliary burner fuel line	-Provides fuel passageway to feed auxiliary burner from main burner unit
13. Auxiliary burner control valve	-Opens auxiliary burner fuel line. Allows fuel to feed into auxiliary burner for lighting.
14. Grate	-Grid above burners for pans to sit on while burners are in operation.

Figure 3. Equipment Parts & Purposes

the system. The spine can be isolated by asking—what is the major purpose of the system? In the case of a plastic pipe extruder it would be to make pipe. Thus, the analyst would follow the flow of plastic pellets and their conversion to a finished product. Inputs, processes, and outputs would be noted and graphically portrayed on the system flow sheet. Once the spine was flowcharted, the several sub-systems, such as raw material handling and heat distribution and control, would be added.

Equipment Parts and Purposes

The equipment parts and purposes analysis yields the proper nomenclature and functions of various tools or parts of a machine. This functional breakdown provides part by part knowledge, jargon, and understanding that will ultimately facilitate troubleshooting analysis. One rule of thumb is that if the worker interacts with a part directly or indirectly (e.g. through a control system), it should be included. Additionally, imagine the person who operates the pipe extruder and the person who repairs it. The equipment parts and purposes content (and the content of the other components of the process and troubleshooting analysis) for each of these jobs will differ. Obviously there will be significant overlap of information.

Process and Troubleshooting Analyses

The process analysis defines the theory of a complex process in operational terms. The process analysis calls for process variables and their specifications, indicators, controls, and effects within the process(es).

The last component, troubleshooting analysis, yields the diagnostic flow of knowledge needed to respond to a failing or inoperable system. In this final component the flow, equipment parts and purposes, and process analyses are synthesized for the understanding of troubleshooting.

Case Study

For the purpose of illustrating process and troubleshooting analysis, an analysis for the operation of a simple and reasonably familiar device is included. This analysis is of the operation of the Coleman camp stove.[1] Readers are reminded that an equivalent analysis of a complex piece of manufacturing equipment would constitute a much greater commitment to analysis time and paper products documenting the findings. The system flow (Figure 2), equipment parts and purposes (Figure 3), process (Figure 4), and troubleshooting analysis (Figure 5) for the operation of the Coleman camp stove follow.

Conclusion

In conclusion, there appear to be two important issues not yet answered. These include a look at the investment-return of process and troubleshooting analysis and the determination of when it is appropriate to conduct a process and troubleshooting analysis.

The investments are primarily time investments on the part of skilled analysts. This analysis work is typically in addition to standard job and task analysis. Work behavior that is primarily linear or procedural in nature may not require a process and troubleshooting analysis. Work that requires continuous human monitoring and multiple interactions with systems may be fair game for process and troubleshooting analysis. The costs should be judged against anticipated gains in worker knowledge and skill. Process and troubleshooting should ultimately expose

CONDITION OR VARIABLE	SPECIFICATION	INDICATOR	CONTROL	EFFECT OF:		OTHER INFORMATION
				PLUS DEVIATION	MINUS DEVIATION	
Air pressure in fuel tank	35 strokes of air pump if fuel tank full. More if tank less than full	Memory of operator plus amount of flame at "full open" position of feed flow valve wheel	Action of the operator upon air pump	None	Low burning flame Poor heat output Wavering, uneven flame	As air pump is operated, increased resistance to pumping strokes will be noticed as air pressure of fuel tank rises
Fuel flow to main burner	Open fuel flow valve as needed	Visible "size" of flame at burner	Fuel flow valve wheel	Large, high heat output flame	Small, low heat output flame	specification controlled by operator needs
Fuel flow to auxiliary burner	Open auxiliary burner control valve as needed	Variable "size" of flame at burner	Auxiliary burner control valve	Large, high heat output flame	Small, low heat output flame	Main burner flames will lessen when auxiliary burner is in operation

Figure 4. Process Analysis

itself in the form of increased productivity and decreases in system downtime and/or product waste. Judged in this manner, industry will find the costs of process and troubleshooting analysis minuscule when compared to the financial gains.

PROBLEM	CAUSE	CORRECTIVE ACTION
-Small or "low" flame	-Low air pressure in fuel tank -Too little opening of fuel flow valve -Low fuel	-Operate air pump to increase air pressure on fuel -Open fuel flow valve wider - turn flow wheel counterclockwise -Add fuel to fuel tank
-Large or "high" flame	-Fuel flow valve too far open	-Shut fuel flow valve down - turn flow wheel clockwise
-Burner will not light	-No fuel -Low air pressure -Clogged fuel passageways -Foreign substance in generator gas tip -Flame ignition source faulty	-Fill fuel tank -Operate air pump to increase air pressure on fuel -Disassemble and clean all fuel passageways -Rapidly rotate fuel flow valve wheel from open to closed several times -Replace or service ignition source
-Orange, unsteady flame (blue, steady flame when properly operating)	-Fuel flooding -Fuel lighting lever left in "Up to Light" longer than one minute -Wind interference	-Close fuel flow valve wheel - allow flame to burn out - check for obstructions in fuel lines and fuel and air mixing chamber - clear obstructions - relight stove -Turn fuel lighting lever to "Down to Burn" position -Adjust wind baffles - turn stove so back shield and side baffles block wind
-Unsteady, sputtering flame immediately after lighting	-Fuel lighting lever in "Down to Burn" position	-Shut flame off - turn fuel lighting lever to "Up to Light" position - relight stove

Figure 5. Troubleshooting Analysis

[1]The authors wish to acknowledge Max Gernand, Rochester, Minnesota for the analysis case study cited.

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