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<u>Note on Vigilance and Process Con-trol</u>

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My immediate reaction to a question concerning the significance of "vigilance" in industrial process operators was that "vigilance" is not particularly relevant in modern plants having automatic monitoring and alarm systems. Especially in computerized systems there is good opportunity for early warning systems. This is probably due to the tight relation in literature to a specific military type of work situation; to quote Meister: "Vigilance tasks are most often performed in the real world by a sonar operator or radar man; as a rule stimuli are only slightly above threshold "The literature on vigilance is vast because this task has generated great experimental interest....... We do not know exactly why the interest is so great, but what is apparently vigilance behaviour is found in many systems, both military and civilian, and the task is superficially easy to set up in a laboratory. Nevertheless, the laboratory vigil is extremely specific, and conclusions reached from it do not necessarily generalize to other types of situations."

In spite of automatic monitoring systems, process operators do have situations when he is looking out carefully for critical stimuli e.g. starting up a system after repair and looking for abnormal reactions from system parts or instruments. However, on second thought operator "vigilance" appears to be extremely important if a slight shift in semantics is allowed. The term is then related to the readiness of an operator to respond with the proper mental mechanisms rather than the readiness to detect the need to respond.

Some typical case stories will illustrate my point. The cases fall in two different categories.

Cases of the first category:

Case:

During normal operation of a process plant the power supply to the instrumentation and the control console slowly disappears.

Investigation:

The manual main circuit breaker in the flywheel motor-generator supply is found to be in the off position. The conclusion of an investigation was that a roving operator, checking cooling towers and pumps, inadvertently had switched from a routine check round to the Friday afternoon shut down check round and turned off the supply. The routes of the two check rounds are the same, except that he is supposed to pass by the door of the generator room on the routine check, but to enter and turn off the supply on the shut down check. Something "en route" obviously has conditioned him for shut down check (sunshine and day dreams?). The operator was not aware of his action, but did not reject the condition.

Case:

An experimental plant shuts down automatically during normal operation due to inadvertent manual operation of cooling system shut off valve.

Investigation:

A safety shut off valve in the cooling system which is routinely closed during post shut down check procedures was closed manually. The valve control switch is placed behind the operating console, and so is the switch of a flood lightning system used for special operations monitored through closed circuit television. The switches are neither similar not closely positioned. The operator has to pass the valve switch on his way to the flood light switch.---

In this case the operator went behind the console to switch off the flood light, but operated the shut off valves which caused plant shut down through the interlock system.

Comments:

Strongly automated and stereotyped action sequences are frequently initiated by a single conscious decision. If the action takes some time, e.g., you have to move to another place to perform the action, the mind may return to other matters, and the sequence is vulnerable to unpredictable conditions, particularly if the sequence intended in some of the steps overlap other familiar and automated sequences.

This category exemplifies absentmindedness, lack of selfmonitoring or lack of vigilance.

One reason to have human operators in process systems is the human versatility as a movable manipulator and controller. In this function many tasks are automated or stereotyped and often so numerous and simple that they are not planned or described. Nevertheless, they form the background of numerous habits, capable of interfering with more critical tasks.

Some cases belonging to the second category:

Case:

Butadiene explosion at Texas City.

Plant Safety and Loss Prevention. Volume 5, CEP.

Investigation:

"Loss of butadiene from the system through the leaking overhead line motor valve resulted in substantial changes in tray composition ..."The loss of liquid in the base of the column uncovered the calandria tubes, allowing the tube wall temperature to approach the temperature of the heat supply. The increased vinylacetylene concentration and high tube wall temperature set the stage for the'explosion which followed".

... "The make flow meter showed a continuous flow; however, the operator assumed that the meter was off calibration since the make motor valve was closed and the tracing on the chart was a straight line near the base of the chart. The column base level indicator showed a low level in the base of the column, but ample kettle vapor was being generated".

Comment:

Wisdom after the event tells that closed valve together with continuous flow signals possible leak, and the risk implied calls for investigation. The skilled operator, however, confirms his observations individually with his expectations or process feel. If abnormal observation refers to a familiar situation, he sees no problem and does not investigate the matter. You cannot predict his response without knowing his daily experiences. It can be difficult to predict the probability that an operator performs a specified function because he may have respecified his function sometimes with good reason.

This can happen, even if there is a clear prewarning:

Case:

Melt down of fuel element in nuclear reactor. Nuclear Safety, September 1962.

Investigation:

Certain tests required several hundred process coolant tubes to be blocked by neoprene disks. 7 disks were left in the system after the test, but were located by a test of the gauge system that monitors water pressure on each individual process tube. For some reason the gauge on one tube was overlooked, and it did not appear in a list of abnormal gauge readings prepared during the test. There was an ' additional opportunity to spot the blocked tube when a later test was performed on the system. This time the pressure for the tube definitely indicated a blocked tube. The shift supervisor failed, however, to recognize this indication of trouble. The gauge was adjusted at that time by an instrument mechanic to give a midscale reading which for that particular tube was false. This adjustment made it virtually certain that the no flow condition would exist until serious damage resulted.

This category also contains my favourite case story:

In his book "A Study of Thinking'! Bruner (1956 p. lo4) mentions as an example of the classical human failure Lalande, who failed to discover the planet Neptune in 1795. Quotation:

> The incident in question occurred in 1795, nine Years after the discovery of the planet Uranus, and the principal figure involved was the great French astronomer Lalande. In that year Laliinde failed to discover the planet Neptune, although the logic of events should have led him to it. Lalande was making a map of the heavens. Every night he would observe and record the stars in a small area, and on a following night would repeat the observations. Once, in a second mapping of a particular area, he found that the position of one star relative to others in that part of the map had shifted. Lalande was a good astronomer and knew that such a shift was unreasonable. He crossed out his first observation of the shifting point of light, put a question mark next to his second observation, and let the matter go. And so, not until half a century later did Neptune get added to the list of planets in the solar system. From the aberrant movement, Lalande might have made the inference not that an error had been made but that a new planet of the solar system was present. But be was reason-

able. And it was more reasonable to infer that one bad made an error in observation than that one had found a new planet.

This example very nicely illustrates the reactions typical of the human operator in a task of identification or diagnosis. In his mental transformation model Lalande did not refer to a physical system, but he recorded data according to a formal routine. His goal was to collect and record numbers, not to study a physical system; and finally he did not even consider the consequence of his data being correct (the immediate risk) to such a degree that it made him repeat the measurement.

The conclusion is that the operator's mental transformation model of the plant varies fundamentally according to his working conditions, and therefore the coding of data sets will have to change in accordance with the nature of the actual task. These changes should be performed not only to ensure a high information input capacity, but also to break the operator's routines and ensure operation based upon a relevant system model and a proper goal.

In these cases, the operators are not responding absentmindedly. They realize a problem, choose very reasonable interpretations of the circumstances and react by convenient, familiar responses. The problem is basicly related to one of the very reasons for man's presence in the system, his adaptability. He will create a repertoire of routines which generally have a high probability of success; on the average he can perform effectively following the "law of least resistance".

However, we are not only concerned with quality of average performance. Some chains of events will lead to very drastic consequences and can of course only be expected with extremely low probability, but at the same time high quality operator performance is important when they appear. The vigilance problem is the need for the operator to see through the characteristic signals which are so efficient on the average and be aware of the defining signals which are needed in critical encounters.

In conclusion, vigilance is important in process control, but a kind of "cognitive" vigilance, rather than the "perceptive" vigilance of radar operators.

There are three basic reasons for the presence of operators in modern systems:

- He is a versatile and locomotive manipulator or multipurpose controller, taking care of a host of simple tasks or task elements for which he will have "absent-minded" routines.
- He is a learning and adaptive data processor able to develop heuristic decision rules or associations to relate efficiently characteristic sign to effective actions, which will compensate for the more frequent disturbances and design weaknesses of the system.

- He is an intelligent problem solver capable of causal reasoning. He can generate specific action sequences to counter unforeseen system conditions.

A process operator in the first situation of trivial, stereotype tasks must be "vigilant" if he should be expected really and consciously to see the events in his environment and to monitor his own activities. Also, a process operator has to be "vigilant" to realize a problem, to think in a situation where familiar routines immediately offer probably successful effects and push him past the point of no return.