

Application of HFE Countermeasures to Improve a Space Restricted Workstation in the Laboratory

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Introduction

Poorly designed workstations have several disadvantageous effects in the workplace. For example, some negative aspects are inefficient work output, errors in work, and development of cumulative trauma disorders (CTDs). However, the application of human factors engineering (HFE) principles counters and prevents the adverse effects of poorly designed workstations, which result from the oversight of basic human factors. Human factors engineering is an applied science that takes research about human abilities, limitations, behaviors, and processes and uses this knowledge as a basis for the design of tools, products, and systems. (Beith, 1999) Applying human factors principles leads to designs that are safer, more acceptable, more comfortable, and more effective for accomplishing their given tasks. (Beith, 1999) Moreover, ergonomic recommendations for the proper design of workstations make work easy and efficient. (Kroemer, Kroemer, Kroemer-Elbert, 2001) There are several types of problems associated with the various workstations in a typical manufacturing facility. For instance, some problems may be inappropriate or lack of workstation furniture, the location of a workstation, and the space for a workstation. Fittingly to the information discussed thus far, the topic of this paper is the evaluation and identification of HFE hazards and issues with a space restricted workstation in the laboratory of a manufacturing-type facility. After surveying the conflicts of the workstation to HFE principles, there were several problems associated with the space restricted workstation in the laboratory, which included user discomfort, complaints, and dangers. Furthermore, the scope of this paper addresses the application of HFE countermeasures to improve the space restricted workstation in the laboratory.

Background

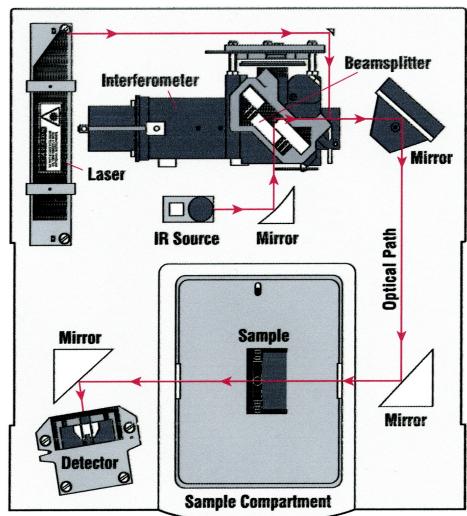
FT-IR General Information

The space restricted workstation in the laboratory for this term project involves an instrument called the Fourier transform – infrared (FT-IR) spectrometer. An FT-IR spectrometer is used to perform physical chemistry tests on a sample. Specifically, an FT-IR spectrometer detects the vibration characteristics of chemical functional groups in a sample. (Nuance, 2008) The analyses performed by FT-IR spectroscopy are usually qualitative, but it can also be used for quantitative purposes as well. FT-IR spectroscopy can provide the following:

- identify unknown materials,
- determine the quality or consistency of a sample, and
- determine the amount of components in a mixture. (Thermo Nicolet, 2001)

Usually, an FT-IR workstation consists of a spectrometer and a computer. The components of a typical FT-IR spectrometer are an infrared light source, laser, interferometer, beamsplitter, mirrors, sample compartment, and detector (Fig. 1).

A Simple Spectrometer Layout



(Thermo Nicolet, 2001)

Figure 1. This is the layout of Thermo Fisher Scientific's FT-IR model Nicolet 380. The basic components of an FT-IR spectrometer are similar to this layout.

FT-IR Requirements

Due to the requirements of an FT-IR workstation, careful HFE actions should be taken to ensure proper functionality, comfort, and work efficiency. Often designing a workstation in the laboratory, such as an FT-IR workstation, can be challenging due to space constraints and other factors. In addition, sometimes certain requirements of an instrument determine where it must be placed, which results in a space restricted workstation (Fig. 2).

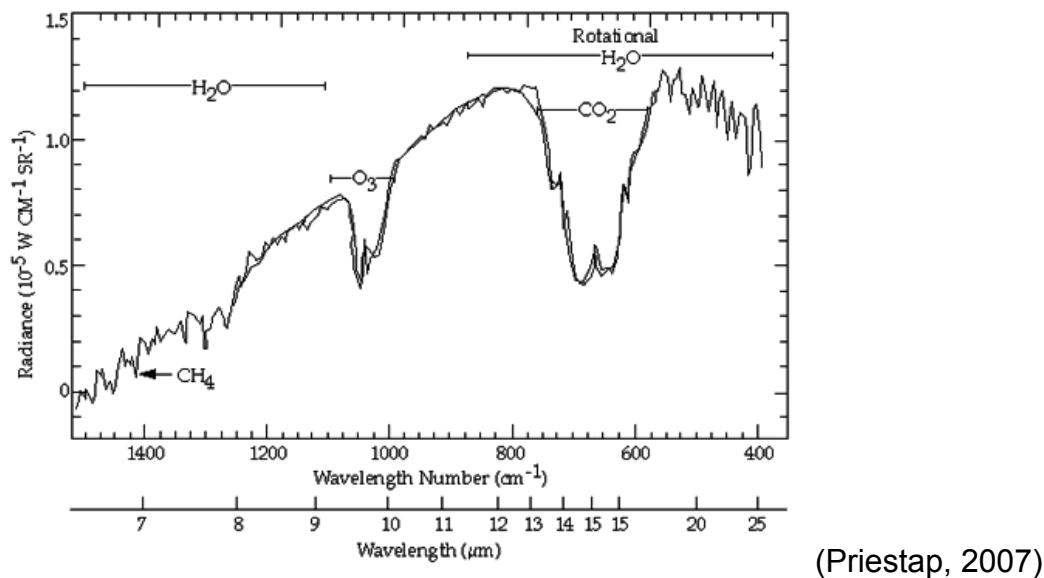


Figure 2. This is a photograph of the space restricted FT-IR workstation in the laboratory for this term project. The FT-IR is a Thermo Fisher Scientific Nicolet 380 model. The location of the purge gas (nitrogen) line determined the location of the FT-IR workstation.

The basic requirements of a typical FT-IR workstation are:

- a power outlet,
- a sturdy work bench free from vibration,
- a computer with that meets the minimum software requirements, and
- a purge gas.

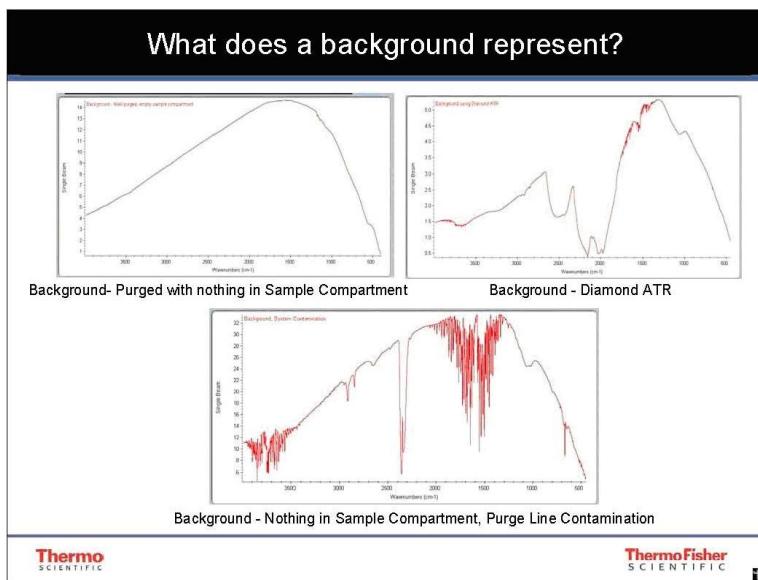
Depending on what region of the world the FT-IR spectrometer is used, the instrument has to be plugged into either a 110-volt or 220-volt power outlet. Besides the power outlet requirement, the work bench that the instrument is placed on needs to be free of vibrating devices because the FT-IR spectrometer detects vibrational energy emitted from a sample when submitted to infrared light. Thus, if there are other vibrations that occur during sample analysis, the FT-IR spectrometer mostly likely will not be able to detect the vibrational energy emitted from the sample correctly. In addition to the work bench, a computer is needed because it interfaces with and controls the FT-IR spectrometer, as well as analyzes the results via software. Finally, a purge gas is needed to reduce the carbon dioxide (CO_2) and water (H_2O) in the atmosphere because CO_2 and H_2O have very strong peaks that appear in FT-IR analysis, which is called the FT-IR spectrum. An FT-IR spectrum is the plot of absorption intensity versus wavenumber of the sample. (Pavia, Lampman, & Kriz, 2001) In regards to the purge gas, typically either dried air or nitrogen is used; the latter is preferred. Furthermore, gas cylinders are not recommended because usually a significant amount of purge gas is required to properly ensure sufficient purge of CO_2 and H_2O , which depends on the frequency and duration of sample analysis. Instead, an in-house purge gas system is recommended for an FT-IR spectrometer. Commonly, a background of the atmosphere is taken, which is used to subtract the CO_2 and H_2O present during sample analysis (Fig. 3).



(Priestap, 2007)

Figure 3. The most common contaminants that appear in a background spectrum are CO_2 and H_2O present in the atmosphere.

Although the software of an FT-IR spectrometer can subtract the components such as CO₂ and H₂O present in a background from the sample spectrum, a poorly purged or unpurged FT-IR spectrometer results in extra unwanted peak detection in the final sample spectrum. Background spectra vary depending on several factors, such as sufficient purge of the instrument (Fig. 4).



(Murphy, 2007)

Figure 4. As an over-emphasized illustration, the background with proper purge shows no peaks in the background spectrum. However, this is never realistically achieved because despite even excessive purge, CO₂ and H₂O are always detected in the background. The other background with the diamond ATR shows the detection of the diamond crystal from attenuated total reflectance (ATR) analysis. Finally, the background with poor purge shows a significant detection of CO₂ and H₂O contamination present in the atmosphere.

Difficulties with Relocation

The factors that determine the location of an FT-IR workstation are the requirements mentioned previously. In particular, the location of the purge gas line is a very important determining factor for the location of an FT-IR workstation. Even if the purge gas line is not an issue, there are other difficulties with moving an FT-IR workstation in a laboratory. Some of the difficulties are:

- space,
- requalification – Performance Qualification (PQ) (only if the FT-IR spectrometer has already been qualified),
- weight and bulkiness of the instrument, and
- delicateness of the instrument and its internal components.

Analysis

Ergonomics

First, an evaluation of the FT-IR workstation was performed. A well-designed and appropriately-adjusted [work surface area provides] adequate clearance for [the employee's] legs, allow proper placement of computer components and accessories, and minimize awkward postures and exertions. (Occupational Safety & Health Administration, 2008) Apparently, the FT-IR workstation had several conflicts in design according to HFE principles, particularly to ergonomic conditions. Hence, the first step in evaluating the overall design of the FT-IR workstation was determining the current ergonomic conditions for users. To start, height measurements relating to the computer aspects of the FT-IR workstations were recorded (Table 1).

Table 1. The computer components of the FT-IR workstation were measured, using the floor as the reference start point.

Workstation Component	Height above the Floor (cm)
Keyboard Support	92
Screen Center	111
Work Surface	92

Considering that the computer-interfaced FT-IR workstation was located in the laboratory, the widely documented HFE computer workstation recommendations differed greatly from the measurement found in Table 1. In fact, Kroemer et al.'s suggested HFE computer workstation component heights for typical and adjustable video display terminal (VDT) workstations (Table 2) differed from the actual height measurements of the computer-interfaced FT-IR workstation in the laboratory (Table 1) significantly. The reason was that the work surface in the laboratory, in this case-the work bench, was much higher than an office workstation's work surface-the desk.

Table 2. These are the recommended HFE ranges for VDT workstation heights measured above the floor in cm. The heights are for a typical VDT workstation as well as for three different scenarios. The first scenario (third column) is the recommended HFE height ranges for a VDT workstation with all adjustable components. The second scenario (fourth column) is for a VDT workstation with a fixed work surface height. Finally, the third scenario (last column) is applicable to a VDT workstation with a fixed seat height.

Workstation Component	Typical (cm)	All Adjustable Components (cm)	Fixed Work Surface (cm)	Fixed Seat (cm)
Seat Pan	37-50	37-50	50-55	(fixed at 50)
Keyboard Support	60-70	53-70	(fixed at 70)	65-70
Screen Center	60-130	93-122	106-127	106-122
Work Surface	60-70	-----	(fixed at 70)	-----
Footrest	-----	Not Needed	0-18	0-13

(Kroemer et al., 2001)

Despite the discrepancies between the recommended heights for a VDT workstation (Table 2) and the actual heights for the computer-interfaced FT-IR workstation in the laboratory (Table 1), the ratio of the component heights were still taken into consideration for improvement. However, during the evaluation of the FT-IR workstation, the question of the operating posture for the workstation arose. In particular, the debate over whether the FT-IR workstation should operated while standing, sitting, or standing and sitting surfaced. In order to determine which posture was best-suited for the FT-IR workstation, a few questions had to be answered. First, the typical duration spent at the workstation was a crucial determining factor. The FT-IR workstation was mainly used for raw material identification testing and initial experimentation with the software as well as the spectrometer. These activities were typically 30 minutes to 1 hour in duration. However, more detailed time-consuming research and development related activities that may be performed in the future were also considered. In addition to the activities with the FT-IR workstation, another very important factor that weighed heavily on the determination of the operating posture for the FT-IR workstation was the input from users. Users complained that the FT-IR workstation was not convenient for a standing operating posture due to the operation time with the workstation. Thus, it was determined that a seated posture for the workstation was best for users considering its applications. In fact, people should never be forced to stand at workstation just because the equipment was originally ill designed or badly placed. (Kroemer et al., 2001) However, the possibility and versatility to be used with a standing operating posture was pondered, too.

There was a major HFE hazard with the decision to designate the FT-IR workstation as a seated workstation. Despite the several benefits over a sitting operating posture versus a standing operating posture, such as allowing better-controlled hand movements, designing a workstation for a seated operator must take into consideration the free space required by the legs and feet. (Kroemer et al., 2001) Apparently, the FT-IR workstation was placed in an area that was meant to have a seated operator (Fig 5). With a severely limited space, very uncomfortable and fatiguing body postures result, such as low back pain and foot swelling. (Kroemer et al., 2001)



Figure 5. The FT-IR workstation in the laboratory was obviously not originally intended to be used with a seated posture. However, several of the chemists were operating the workstation while sitting due to the duration of the activities performed.

Clutter and Disorder

Besides the ergonomic conditions of the FT-IR workstation, the clutter surrounding the workstation was noted. The work area should be large enough to accommodate [the employee], allow the full range of motions involved in performing required tasks, and provide room for the equipment and materials that make up the workstation. (Centers for Disease Control and Prevention, 2000) Although the FT-IR workstation was located at the end of the work bench, the space adjacent to the workstation was unorganized and created a sense of disorder (Fig. 6). Furthermore, limited space on the work surface may cause users to place components and devices in undesirable positions, which may lead to awkward postures. (Occupational Safety & Health Administration, 2008)



Figure 6. This is a photograph of the clutter on the FT-IR workstation's work bench. Several devices and another computer workstation crowded the FT-IR workstation's work bench.

The crowdedness of the work bench brought further attention and inquiry to the current importance, usage, and relevance of the adjacent devices to the FT-IR workstation. Immediately adjacent on the left of the FT-IR workstation was another computer workstation. The computer workstation was primarily used for printing labels (Fig 7). Its only requirements were a 110-volt power outlet and an Ethernet outlet to connect to the internet and company network. Thus, the computer workstation's requirements were not binding to keep it at its current location because there were several other power and Ethernet outlets in the laboratory. As such, the possibility for the computer workstation used primarily for printing labels to be moved in order to free up space around the FT-IR workstation was an option. As a result, some of the benefits of maintaining high housekeeping standards include:

- efficient space utilization within workspaces due to organization,
- more efficient time management due to organization of materials records data,
- improved control over resources due to better maintenance and organization of those resources,
- conservation of resources, since resources can be better maintained and most efficiently utilized,
- fewer mishaps or accidents that lead to injury requiring Workers Compensation,
- increased production time due to most efficient utilization of space, most efficient materials-movement, and
- higher moral due to the improvement in the working and learning environment. (University of Western Sydney, 2004)



Figure 7. This is a photograph of the computer workstation adjacent to the FT-IR workstation. This workstation is used primarily for printing labels. The computer workstation did not have any requirements that bound it to this location permanently.

Further down the bench, there were three (3) temperature-controlled water baths. These water baths were very bulky and occupied much space (Fig 8). A deeper investigation of the usage and applications for these water baths revealed that they were not used for more than a year. In fact, they were used for release kinetics (RK) testing, often otherwise called dissolution testing, for a previous product that was cancelled over a year ago. Furthermore, the possibility of future usage for these water baths was very unlikely because the decision had been made to use a different RK apparatus called the USP 4, which was more commonly accepted by the Food and Drug Administration (FDA).



Figure 8. This is a photograph of the three (3) bulky water baths that had not been used in over a year. These water baths occupied a large portion of the work bench. Future usage of these water baths was very unlikely due to the implementation of a different RK apparatus, which is more commonly accepted by the FDA.

Location and Storage of Supplies and Accessories

In addition to the space on the work bench, the drawers and cabinets below the bench were also examined for proper and logical location. Furthermore, the labeling of the drawers and cabinets were also analyzed. Most of the drawers and cabinets were neatly organized and labeled. However, the drawers and cabinets near the FT-IR workstation were illogically organized and inconsistently labeled (Fig. 9). A drawer directly below the FT-IR workstation was labeled and used for the storage of printer labels and accessories belonging to the adjacent computer workstation. Also, another drawer directly below the FT-IR workstation was not labeled at all. Finally, the labels of the cabinets were not descriptive and printed in different font sizes.

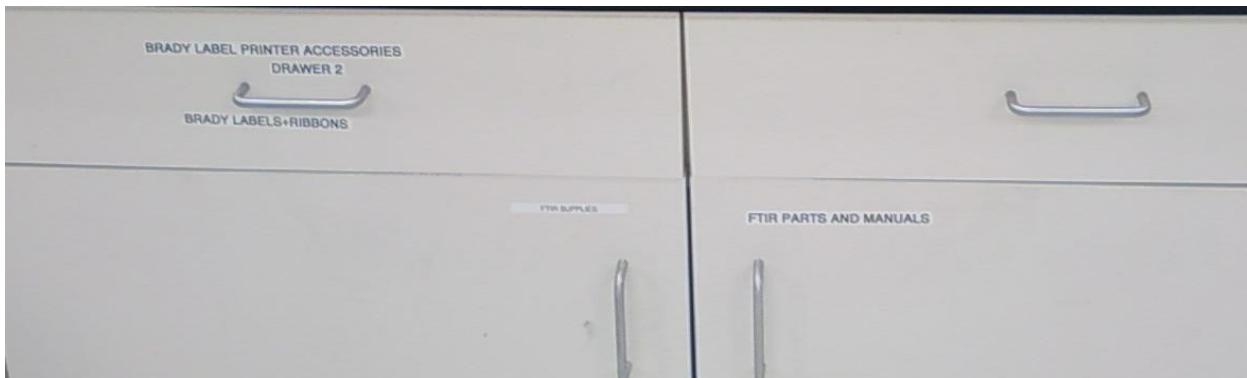


Figure 9. The drawers and cabinets directly below the FT-IR workstation were illogically organized and inconsistently labeled.

Not only was the labeling of the drawers and cabinets an issue, but the contents inside the drawers and cabinets were not appropriately arranged. As mentioned previously, one of the drawers directly below the FT-IR workstation was incorrectly designated for accessories of an adjacent workstation. As for the other unlabeled drawer, several items were stored in the drawer (Fig. 10). The drawer was over-stuffed with various FT-IR related items. Finally, the vaguely labeled cabinets contained items unrelated to the FT-IR workstation (Fig. 11). Evidently, the cabinets were used for storage of general items in the laboratory. The organization and arrangement of items in the drawers and cabinets below the FT-IR workstation did not have any logic to them. Clearly, the drawers and cabinets below the FT-IR workstation needed reorganization and relabeling.



Figure 10. The unlabeled drawer below the FT-IR workstation contained several items that were related to the FT-IR. However, there was no logic for the arrangement and placement of the items in the drawer. There were sample preparation supplies and accessories, logbooks, instruction manuals, reference standards, tools, and other items all in the same drawer.



Figure 11. The cabinets below the FT-IR workstation contained only a few related accessories and the empty original packaging box of the FT-IR spectrometer. On the lower shelf, there were unrelated consumable laboratory items, such as paper towels and absorbable work bench mats.

Interference to the FT-IR Workstation

The final HFE issue that was found during the analysis of the FT-IR workstation was the interference factor from the adjacent devices on the work bench. There were two (2) sonicator baths (Fig. 12) and a digital multi-tube vortexer (Fig. 13) located on the same work bench as the FT-IR spectrometer. As mentioned in the background section of this paper, the placement of these devices on the same work bench was a direct conflict to a requirement of the FT-IR spectrometer. As a reminder, a requirement of the FT-IR spectrometer was the necessity for placement on a work bench free from vibration. In this case, both the sonicator baths and the vortexer created vibrations. In addition, both of these devices were used frequently. This not only presented a problem for producing accurate results from the FT-IR spectrometer, but it also created HFE issues for the users as well. If a sonicator bath or the vortexer was in use, then the operator of the FT-IR workstation had to wait until the sonication or vortex was complete before proceeding with usage of the instrument. Obviously, this caused an inconvenience and delayed the processes for sample analyses.



Figure 12. The two (2) sonicator baths were located to the left of the computer workstation used primarily for printing labels. These sonicator baths were used very frequently in the laboratory. The typical duration of sonication was fifteen (15) minutes.



Figure 13. The digital multi-tube vortexer was located next to the sonicator baths on the work bench. Like the sonicator baths, this device was also used frequently in the laboratory. Furthermore, this device created very strong vibrations during operation. The typical duration of vortex was thirty (30) minutes.

Intervention

Ergonomics

Due to the decision to designate the FT-IR workstation primarily as a seated workstation, the HFE countermeasures required the purchase of a few ergonomic accessories. Because the work bench was higher than the usual office desk and the fact that the workstation was not meant for seated operation, a desktop adjustable keyboard drawer was purchased. The adjustable keyboard drawer not only allowed the user to work at the FT-IR workstation in a seated posture, but it also gave the flexibility to use the workstation while standing. This was possible because of the adjustable height feature of the keyboard drawer and the adjustable viewing angle feature of the monitor. In addition, the adjustable drawer resolved the issue of leg space for the seated operator. Furthermore, the keyboard drawer came with an antimicrobial keyboard wrist rest, which was not used, and a mouse pad that optimized the performance of optical or laser mice.

Besides the adjustable keyboard drawer, a wireless ergonomically-designed keyboard and mouse combination was purchased. The keyboard featured an ergonomic wave design that included a cushioned palm rest and contained several convenient easy-access keys for Windows. In addition, the laser mouse was ergonomically contoured to either left-handed or right-handed operation. The mouse also included side rubber cushions, a 360° scroll wheel, and programmable buttons. The added versatility of the wireless keyboard and mouse made it very convenient for users.

A mouse wrist rest was purchased as well because the adjustable keyboard drawer did not include one. Furthermore, the adjustable keyboard drawer not only adjusted in height, but it also adjusted in tilt angle. Therefore, the mouse wrist rest not only provided ergonomic relief and prevention to CTDs, such as carpal tunnel syndrome (CTS), but it also blocked the wireless mouse from falling off the adjustable keyboard drawer during steep tilt angles.

Appropriately, an ergonomic laboratory chair was also purchased. After all, the FT-IR workstation was designated to be used primarily while sitting. Although there were other laboratory chairs available, a laboratory chair designated for this specific workstation was fitting. Considering the special circumstances of the workstation, careful selection of an appropriate laboratory chair was made. The laboratory chair consisted of armrests, a wide range in height adjustability, backrest adjustability, a footrest, and ergonomic design (backrest and seat pan). The placement of a footrest in the laboratory was not appropriate or approved. In lieu, a laboratory chair equipped with a footrest was chosen as a substitute.

Finally, as an additional HFE precautionary intervention, a monitor filter was purchased to counter issues against glare. Although illumination was not an HFE workstation topic address during analysis, a decision was made to purchase a filter to ensure against issues of poor or improper illumination. The monitor filter also included other features, such as privacy viewing and anti-radiation protection.

The overall setup of the ergonomic accessories addressed and countered many of the issues for the workstation that were found during the analysis process. The total cost for all the ergonomic intervention items was just under \$1000 (Table 3). By adding these items, the FT-IR workstation looked very different (Fig. 14). More importantly, the FT-IR workstation became more suitable to the users.

Table 3. The summary of all ergonomic items purchased for the FT-IR workstation is listed. The table includes the brand, model, and price of the ergonomic accessories for the FT-IR workstation. The items are organized in a Pareto arrangement from greatest to least cost.

Workstation Component	Description	Brand	Model	Price
Chair	Ergonomic Laboratory Chair	Biofit	MM1926ACCRP	\$387.90
Monitor Filter	Display Enhancement	3M	PF400XLB	\$299.99
Keyboard Support	Desktop Adjustable Keyboard Drawer	3M	KD95CG	\$199.99
Keyboard & Mouse	Ergonomic Wireless Keyboard & Mouse	Logitech	Cordless Desktop Wave	\$99.99
Mouse Wrist Rest	Gel Mouse Wrist Rest	3M	WR305LE	\$7.49
Total				\$995.36



Figure 14. This is a photograph of the modified and newly designed computer portion of the FT-IR workstation. All workstation components listed in Table 3 are shown in the photograph except for the ergonomic laboratory chair.

The modification of the FT-IR workstation effectively allowed users to perform tasks in a standing or sitting posture. In addition, the modification of the FT-IR workstation also changed the heights of the workstation components as intended (Table 4.)

Table 4. The workstation components heights were measured in cm above the floor. The keyboard drawer was adjustable; therefore, the height above the floor varied. Although a separate footrest was not purchased, the laboratory chair included a footing. However, the laboratory chair was on backorder with a scheduled ship date on 14Apr08. Therefore, the heights for the seat pan and footrest were not available at this time. These heights will be determined upon arrival of the laboratory chair.

Workstation Component	Height above the Floor (cm)
Seat Pan	TBD
Keyboard Support	81-94
Screen Center	130
Work Surface	92
Footrest	TBD

Clutter and Disorder

Based on the investigation of the current and future usage for the three (3) RK water baths, the first step in correcting the clutter and disorder issue was removing the water

baths from the work bench. The water baths were moved to storage because of their inactivity. Evidently, the removal of the three (3) water baths created much more free space on the work bench.

In addition, the computer workstation adjacent to the FT-IR workstation was moved further away due to the available space on the work bench. This allowed more space near the FT-IR workstation, which gave the option for placing accessories and samples next it during analyses.

Location and Storage of Supplies and Accessories

The drawers and cabinets directly below the FT-IR workstation were designated strictly for the FT-IR workstation. Consequently, one of the drawers directly below the FT-IR workstation that was being used for another workstation had to be cleared, and the items were moved to the corresponding location. The emptied drawer was then used for storing accessories for the FT-IR workstation, such as sample preparation items (Fig. 15). The other previously unlabeled drawer, which contained practically all of the accessories and supplies for the FT-IR workstation, now only contained items like the logbooks and instruction manuals for the FT-IR workstation (Fig. 16). In regards to the cabinets below the FT-IR workstation, the empty FT-IR spectrometer box was discarded and the unrelated consumable laboratory items were moved to another storage cabinet elsewhere. This freed much of the cabinet space for the FT-IR workstation (Fig. 17). The reorganization of the drawers and cabinets not only made them less compact, but it also instituted logic and order to the placement of supplies and accessories.



Figure 15. The drawer previously used for the label-printing computer workstation was emptied and reassigned for storing FT-IR accessories. The items placed in this drawer were transmittance analysis accessories, polystyrene standards, dessicant, tools, and miscellaneous parts.



Figure 16. The previously unlabeled drawer below the FT-IR workstation was reorganized, and many items were relocated to the adjacent drawer. The drawer was labeled according to its contents. As shown, the contents stored in this drawer were software (CDs), performance verification (PV) binder, instrument logbook, and manuals.



Figure 17. After the removal unrelated and unnecessary items from the cabinet, there was plenty of storage space for items of the FT-IR workstation.

Besides the rearrangement of supplies and accessories in the drawers and cabinets, new and more descriptive labels were created and adhered to the FT-IR workstation drawers and cabinets (Fig 18). For consistency, all the labels were printed in the same font and size. The new labels allowed users to quickly and easily identify the contents in the drawers and cabinets of the FT-IR workstation.



Figure 18. New labels were made for the drawers and cabinets directly below the FT-IR workstation. The labels accurately described the contents inside the drawers and cabinets. Also, all labels were large in size, making them easily readable.

Interference to the FT-IR Workstation

The sonicator baths and digital multi-tube vortexer were removed from the work bench due to their vibration effects during operation. In order to move these devices to a different location in the laboratory, a pair of inactive high performance liquid chromatography (HPLC) instruments was removed from their corresponding work area. The HPLCs were very outdated and no longer in use. In fact, the HPLCs were out of calibration. With several other newer HPLCs in the laboratory, there was no intention or possibility for future use with these two HPLCs. As a result, the work area had free space to place the sonicator baths and multi-tube vortexer. The relocation of these devices conformed to the non-vibration work bench requirement of the FT-IR spectrometer. Also, the relocation of the devices was more ideal and convenient for the users because they were closer to related supplies, such as vials and disposable pipettes. Furthermore, the relocation made more sense because the sonicator baths were next to the sink, which gave quick access to the deionized water source. With the removal of the water baths, the sonicator baths, and digital multi-tube vortexer, there was plenty of space available on the FT-IR work bench (Fig. 19).



Figure 19. Clearly, the workbench of the FT-IR workstation was drastically changed due to the removal of space-cluttering devices and items. There was sufficient space adjacent to the FT-IR workstation for placing samples and analysis related items, such as SOPs and laboratory notebooks. A simple solution like removing clutter made a substantial impact to the FT-IR workstation.

Conclusion

The plan and implementation for intervention to the FT-IR workstation by using HFE countermeasures resulted in several improvements and positive aspects. The modification to the computer characteristics of the FT-IR workstation by adding ergonomic accessories allowed the users to operate in either a standing or sitting posture. The users now were able to choose between postures for their convenience in respect to the duration of the tasks or even in accordance with their mood. The ergonomic accessories provided solutions to many of the HFE issues and hazards with the original design and layout of the FT-IR workstation. In addition, the work bench was cleared from the inactive, yet space-consuming water baths, as well as the interfering and vibrating sonicator baths and vortexer. Furthermore, users were given more working room next to the FT-IR workstation due to the relocation of the adjacent computer workstation. Finally, the drawers and cabinets below the FT-IR workstation were reorganized, rearranged, and labeled, making it more logical and suitable for users. From all the HFE corrective actions taken, the overall end result was very positive and beneficial to users. In fact, all the users were very pleased and grateful for the effects from this term project. Unquestionably, the users and the company really benefitted from this project. Users were able to perform tasks at the FT-IR workstation more comfortably and more efficiently. The company benefitted by the reduction of possibilities for the development of injuries from workers, which would likely result in worker's compensation and reduction in workforce. However, possible future improvements and suggestions were contemplated and observed. Some the possible improvements and suggestions are replacement of the computer monitor with a height-adjustable one, exchanging frequently used glassware stored in the cabinet space

directly above the FT-IR workstation (Fig. 19) with scarcely used ones, and training employees on HFE best practices and awareness.

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