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An Applied Method for Identifying and Evaluating Ducting Nonconformities and the Implementation Status of Change Management in an Industrial Local Exhaust Ventilation System: Checklist Approach

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Abstract

This study aims to provide an applied method for studying the potential problems of ducting systems and the status of change management implementation in a LEVS. This study designed in two sections of providing a self-made checklist for checking compliance with the standards and recommended criteria. The results show that approximately 25% of the branches have changed from the installation/drawings, and the branch connection angle has deteriorated. In any of the 75 elbows used, the recommended R/D ratio is not met. In 47% (7 cases), ducting hoods routes have been selected inappropriately. In addition, the process of managing change in documents and drawings has not taken place from the beginning. According to the results, at the time of delivery and operation of the system, sufficient knowledge and experienced people to study the system, adapt the design data to standards and implement change management is not available, or at least it can be said that this matter is not important and not done. This method can be used as a tool for managing change in order to update documents (systematically), along with highlighting noncompliant standards.

Keywords: Change management, Local exhaust ventilation, Ductwork, Potential problems.

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Introduction

One of the most effective engineering measures in addressing workplace air pollution is the design and implementation of a LEVS. The various sections of the LEV are connected by ductwork. The term ‘ductwork’ refers to all components between the hood, fan and air cleaner. ducting must be designed with care, a task that may be somewhat complicated[1, 2]. The build-up of dust deposits on the internal surface of the ductwork is influenced not only by the flow and the duct velocity but also the ductwork geometry[3, 4]. Determining the number and type of branches and elbows, the ductwork material, and the dimensions of the ductwork components is a timely process that requires precision and patience. Leaks may occur in these areas, which will affect the system's performance[1, 2] Therefore, any weakness in design or implementation, a lack of coordination between the designer and the installation group, or any changes in the appearance of the system without regard for the design principles may hinder the effectiveness of the LEV system as a whole[4]. This indicates the lack of change management in the design and implementation of a LEVS.

Change management involves a broad and detailed discussion and is one of the critical issues facing industrial construction. Changes in construction projects are commonplace and may come from different sources for different reasons and at each stage of the project. This can have significant negative impacts. Change management program in construction/implementation processes are not a minor issue, since the commands are part of the contract and need to be followed, traced and tracked in contracts, approved processes and related documents. For the process of change management, several models and stages are expressed. Failure to track changes is one of the defects of the proposed solutions. In order to address and to develop this issue, innovative and practical solutions that are accepted by the industry are being explored and researched Anyway, there are more factors affect to change management. Which these factors can categorized factors related to projects, design, and site staff and to risk[5-11].

According to a study by Huang in England, most of the companies being studied needed guidance on how change management in engineering. It has also been clearly shown that management of engineering changes, despite its crucial importance to industry, has not received much attention in research and there is gap at the methods to identify changes[7, 11, 12].

Managing change construction includes ways to reduce the impact of changes in different stages; update and control various design changes, drawings, and site inspections at run time; consider the ability to implement designs; and coordination between drawings and documents[7]. Managing change minimizes actions and activities that rely on individuals. Change management involves optimizing the organization and cooperator team in the process structure, improving the quality and frequency of correspondence/communications, sharing knowledge between designers and other field and specialty with applicants and stakeholders. also developing technical knowledge and software skills of designers and the quality of control measures[13] Change management is a complex process that requires a record, path and flowchart for any change. Changing and updating documents is an integral part of the change management process[14-16].

In this regard, the change management process has been emphasized in order to reduce possible errors during the changes implementation[11, 16, 17]. It should be noted that the criteria for design and construction—including the how construction, type and thickness of the duct, the shape and size of the duct, the components used in the ductwork, etc. can be applied to all components of industrial LEV systems. These criteria should be considered when designing and monitoring the LEV system ductwork[2, 4, 18].

In order to monitor the LEVS to maintain efficiency, special procedures are provided at various stages. One of the methods provided is the physical inspection or the visual inspection of the system[19]. One of the important elements in quality control is visual inspection and by implementing quality control in the production process, it is possible to detect inconsistencies and defects[20].

In addition to particulate control, many industrial exhaust streams include VOCs, and emerging abatement approaches such as hybrid non-thermal plasma–catalyst systems are being explored for efficient VOC decomposition[21].

In the visual inspection, outstanding system issues and defects are identifiable. In the initial assessment, the installation errors and some design errors can be detected. Therefore, an inspection must be carried out to confirm or disprove the compliance between the implemented system and the system's drawings/documents[22, 23].

In accordance with the stated points, this study aimed to provide an applied method for identifying potential problems and to follow the change management process through visual inspection in LEV ductwork in one of the steel industries.

Materials and Methods

In preparation for conducting this research, valid scientific sources were reviewed. From them were extracted principles, standards, and recommended criteria that should be considered in the design and implementation of ductwork. The parameters considered were: supports, flanges and cleanout doors, elbows, duct diameter variations, branches, material and number of ductwork parts, three-way valves, channel trunks in the system status quo, documentation and design drawings.

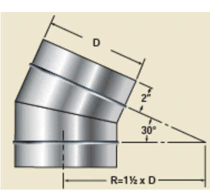
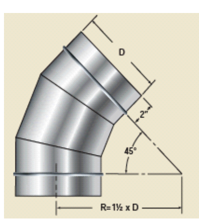
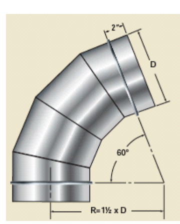
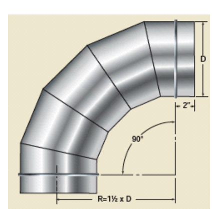
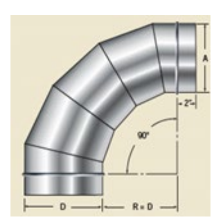
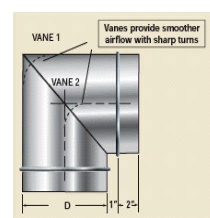
Design study: *The extracted information at before step was used for two purposes:*

A self-made visual checklist (Appendix 1) was derived from the recommended standards and criteria obtained for a) shape and number of parts of the elbows, b) type and location of the branches, c) how to change the diameter of the duct (expansions and contraction) and d) combining the duct change diameter with the branches[2, 4, 18, 22-27]. According to the recommended standards and criteria obtained, responses to each variable were coded as three categories: "unacceptable," "acceptable," and "ideal" (Figure S1).

Subsequently, recommended standards for the design of other ductwork parts were used to create a separate self-made checklist (Table S2). These two checklists (No. 2 and 1) were completed for both drawings and the status quo with the following objectives:

A) Check the conformity of the existing drawings and documents to the standards and design criteria (checking correct design);

B) Check the compliance of the existing status (status quo) for implementation of the system's ductwork with the standard and the installation and executable drawings (including changes made during installation and in the system lifetime). This compliance is monitored using the presence of the unit after the "ground conditions of the work" are completed[23].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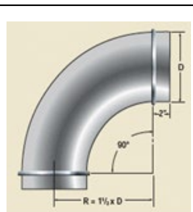
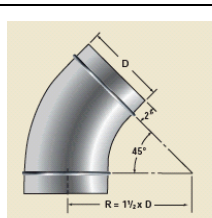
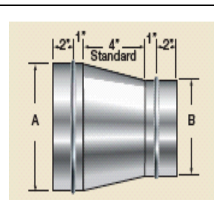
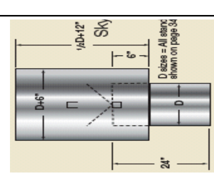
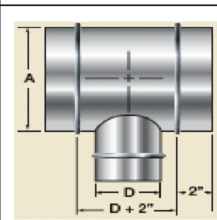
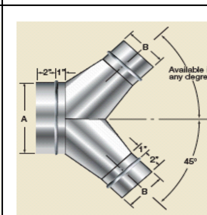
					

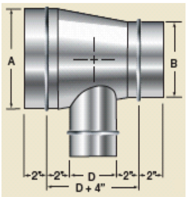
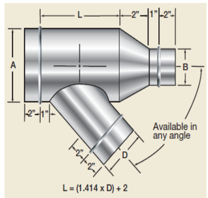
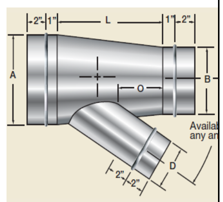
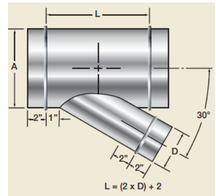
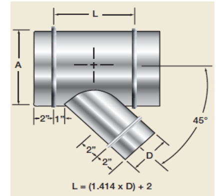
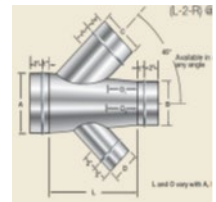
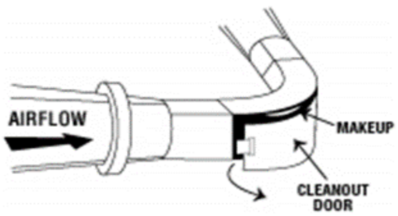
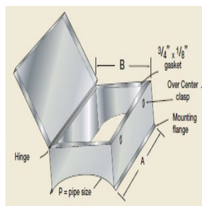
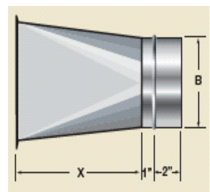
7-preferred	8-preferred	9-preferred	10-avoid	11-avoid	12-preferred
					
13-avoid	14-acceptable	15-preferred	16-acceptable	17-acceptable	18-avoid
					
19-clean out at elbow		20-clean out at duct	21		

Figure S1. Visual checklist components used in system design and drawings

Table S2. Inspection form compliance with duct design standards

Plant name:		**Workshop name:**		**Last date of inspection:**	**Geometry of duct section:**
Date of last changes:		**Inspector:**		**Date of inspection**	**circle rectangle**
Are the data of last changes insert in the inspection form?					
No. of branch entry	**Design** **No. of connected part with respect to table 3-2**	**Branch angle, Elbow angle and R/D ratio, D/L ratio of expansion**	**Existing** **No. of connected part with respect to table 3-2**	**Branch angle, Elbow angle and R/D ratio, D/L ratio of expansion**	**In the correction of the system, angle change, change of duct segment geometry and ... is possible.**
Branch 1					
Branch 2					
Branch 3					
No. of doors in the system	**Type of process**	**Hood type**	**Related VS**	**Dose the VS observed?**	**Is the change or correction possible?**
Hood 1					
Hood 2					
Is the ductwork route acceptable?					
Is it possible to make straight duct length shorter or applying fewer number of elbows?					

Duct inspection of an industrial LEVS usually starts with a field inspection. One proposed method for assessing the accuracy of installation and executable drawings is evaluation of the ductwork layout[28]. The ventilation system under study, used to control iron oxide (Fe_2O_3), was designed in the late 1980s and commissioned later that decade (1988). The ventilation system is composed of wide ductwork with 17 hoods mounted on contamination sources (Figure 1). Ductwork balance is maintained using the velocity pressure method. It should be noted that, at the during time of this research, the guide Table 1 was designed to check change management and to determination which branches have problems.

Figure 1. Ducting design layout of the studied ventilation system

Table 1. Guide the type of sub-branch entries Degree (°) to the main duct (design and status)

Sub-main and branch No.	Qualitative description of branching geometry
1	30-degree, lateral - after expansion
2	45-degree, lateral - after expansion
2.1	45-degree, lateral - after expansion - without respecting the ratio of 1.5 between the increase in diameter and length of the duct
2.2	45-degree, lateral - without loosening
3	60-degree, lateral - after expansion
4	45-degree, below - after expansion - without respecting the ratio of 1.5 between the increase in diameter and the length of the duct
4.1	45-degree, from the bottom - after the expansion
5	60-degree, from the bottom - after the expansion
5.1	60-degree, from the bottom - after expansion - without respecting the ratio of 1.5 between the increase in diameter and the length of the duct
6	30-degree, from the bottom - after the expansion
7	30-degree, from the top - after the expansion
7.1	30-degree, from the top - without expansion
8	45-degree, from the top - after the expansion
8.1	45-degree, from the top - without expansion
9	60-degree, from the top - after the expansion
9.1	60-degree, from the top - without expansion
9.2	60-degree, from the top - after expansion - without respecting the ratio of 1.5 between the increase in diameter and the length of the duct

Through analysis of the obtained data, it was possible to achieve the following:

Review change management by identifying non-conformities between design drawings and the existing status. In order to evaluate the implementation of change management in the system documents, pre- and post-status were determined by comparing the results obtained from the review of drawings and design documents with those obtained from the review of existing system conditions (status quo). The appropriate statistical tests were chosen for the analysis Categorical / Nominal (Chi-square / Fisher's exact) and Ordinal (Mann-Whitney U / Kruskal-Wallis), and changes and nonconformities were recorded and compared with 95% confidence intervals.

Identify defective locations and locations with potential problems that can contribute to system Inefficiency. This was done by comparing the results of the review of the drawings / documents and the existing situation (status quo) with the principles and design standards mentioned in checklists 1 and 2. The appropriate statistical tests were chosen for the analysis with 95% confidence intervals were used[26]. Figures 1 and 2 have shown a summary of the methodology used in this research.

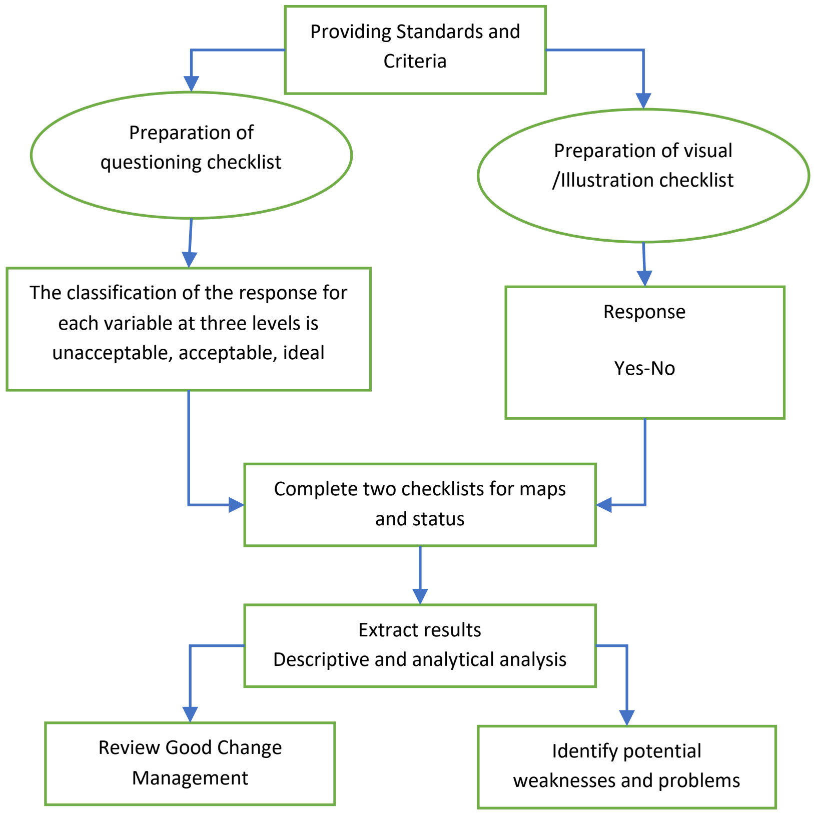


Figure 2. A summary of the study design in this research

Results

Design document review results: In the system documentation are drawings, dimensions, and sections of the main and sub-main ducts, hood locations, fan types, and calculations (manufacturing (as built) drawings, isometric drawings and fan information), but no system design calculation sheet.

Results of the current status of the channeling system: The results for the number of supports, flanges, and cleanout doors contained in the documentation and in the status quo are presented in Tables 2 and 3. There were no three-way valves on the ducting of the system in the status quo. At the entrance to all the hoods, the damper was designed and installed, and it lost its effectiveness over time, and there were steady, motionless and inefficient. As the design of the system was based on the velocity pressure method and the insertion of the damper disturbs the system balance, this (and the insertion of the damper) situation indicates a non-conformity.

Table 2. Results of the study of the number (#) of supports, flanges, and cleanout available in the design and status of the existing

Branch Number,	Support number		Number of flanges		Number of cleanout doors		
Division and Branch System	Existing	Design	Existing	Design	Existing	Design	Requirements based on standard
1	3	3	12	10	0	0	3
2	1	2	5	5	0	0	3
3	2	2	7	6	0	0	3
3.1	8	8	7	7	0	3	2
4	0	0	3	3	0	0	1

5	3	3	7	7	0	0	3
5.1	2	2	5	3	0	0	2
6	2	2	5	5	0	0	3
7	0	0	3	3	0	0	3
8	1	1	6	6	0	0	3
9	3	3	8	6	0	0	2
9.1	3	3	7	5	1	2	2
10	0	0	3	3	0	0	1
11	1	1	6	4	0	0	2
12	1	1	8	4	0	0	2
13	0	0	2	2	0	0	0
14	0	0	2	2	0	0	0
15	0	0	5	3	0	0	1
16	2	2	7	4	0	0	3
16.1	2	2	6	6	0	0	3
17	1	1	4	4	0	0	2
18	1	1	3	3	0	0	1
Total	36	37	121	101	1	5	44
Medium in each section	1.63	1.68	5.5	4.1	0.05	0.23	2

Table 3. Comparison of the results of the average number of supports, flanges, cleanout doors and the angle of branching of the channel to the main system in the design and status quo

	Standard requirements			Design			Status quo		
Measured parameter	**Min-Max**	**Mean±Standard Deviation**	**Total**	**Min-Max**	**Mean±Standard Deviation**	**Total**	**Min-Max**	**Mean±Standard Deviation**	**Total**
Support in each branch (#)				**0-8**	**1.78±1.63**	**36**	**0-8**	**1.78±1.63**	**37**
flanges in each branch (#)				**2-12**	**2.39±5.5**	**121**	**2-10**	**4.1±6.94**	**101**
Cleanout doors in each branch (#)	**0-3**	**0.1±2**	**44**	**0-1**	**0±0.05**	**1**	**0-3**	**0±0.23**	**5**
Branch angle (°)	**30-45**	**3.75±44**	**16**	**45-60**	**5.15±46.88**	**16**	**38-60**	**7.18±48.3**	**16**

Thickness and material of the system components: The results of an examination of the thickness of the elbows to the main duct, the entrances to the main duct, the expansions to the main duct and the hoods to the duct leading to them, plus the material of the elbows, ducts, hoods, and branches in the design drawings are presented in Table 4.

Table 4. The thickness and material of the system components

	Thickness of components to the duct in design					Thickness of components in design			
	The same	**2 degrees more**	**Thinner**	**Same duct diameter**	**Total**	**St-37-2**	**St-35**	**ss-41**	**Total**
Elbow	43 (57.3%)[a]	29 (38.7%)[b]	3 (4 %)[c]		75 (100%)	26 (34.7%)[d]	49 (65.3%)[e]		75 (100%)
Entry	14 (87.5%)		2 (12.5%)		16 (100%)	16 (100%)			
Expansion	7 (41.2%)		9 (52.9%)	1 (5.9%)	17 (100%)	16 (100%)			
Hood	11 (73.3%)		4 (26.7%)					15 (100%)	

a: Multi pieces st-37-2 (24 case (55.8%)). stamped from st-35(19 case (44.2%))

b: stamped from st-35 (29 case (100%)

c: tamped from st-35 (1 case) and st-37-2 (2 case)

d: Multi pieces (24 case). Stamped (2 case)

e: Stamped

System branches: The results of a comparison of the information on the angle, the junction points, the type of branching inputs in the installation and excusable drawings and the existing conditions with used the proposed standard presented in the Tables 3, 5, 6 and 7.

Based on statistical tests, there was no significant difference between the mean of the input angles of the design with the input angle of the existing situation in the branches and the design with the standard. But there was a significant difference between the input angle branches in the existing situation (status quo) with the standard (P-value=0.03).

Table 5. Compare the results of angles, junctions, types of input branches in existing status and design with standard inputs

	Possible situation	Design		Existing		Standard	
		No (#).	Percentage%	No (#).	Percentage%	No (#).	Percentage%
Branch angle (°)	30					1	6.2
	45	14	87. 5	11	68.75	15	93.8
	60	2	12.5	4	25		
	Unknown			1	6.25		
	Total	16	100	16	100	16	100
No. and side of Branch entries to main duct	From the top	3	18.8	3	18.8	3	18.8
	Lateral	11	68.8	11	68.8	13	81.2
	From the bottom	2	12.5	2	12.5		
	Total	16	100	16	100	16	100
No. and geometry of expansion in Branches location	Without expansion	1	6.2	4	25		
	With a ratio of 1.5	12	0.75	8	50		
	Without respecting the ratio of 1.5	3	18.8	4	25		
	Standard Expansion (With a ratio of 1.5)					16	100
	Total	16	100	16	100		

Table 6. Input type of sub ducts to the main duct based on each branch

Branch number	Existing branch entry	Design branch entry	Branch number	Existing branch entry	Design branch entry
1	9.1	8	10	4	4
2	9.2	9.2	11	2	2
4	2.2	2	12	2.2	2.2
5.1	5.1	4.1	13	2	2
6	2	2	14	2	2
7	3	3	15	2.1	2.1
8	2	2	16.1	8	8
9.1	Unknown	2	17	2	2

Table 7. Type and number of used branch entries in design and existing

Number	Branch type	Existing (#)	Percentage %	Design (#)	Percentage %
1	45-degree, lateral - after expansion	6	37.5	8	50
2	45-degree, lateral - after expansion without respecting the ratio of 1.5 between the increase in diameter and the length of the duct	1	6.2	1	6.2
3	45-degree, lateral - without expansion	2	12.5	1	6.2
4	60-degree, lateral - after expansion	1	6.2	1	6.2
5	45-degree, from the bottom - after expansion without respecting the ratio of 1.5 between the increase in diameter and the length of the duct	1	6.2	1	6.2
6	60-degree, from the bottom - after expansion without respecting the ratio of 1.5 between the increase in diameter and the length of the duct	1	6.2		
7	45-degree, from the bottom - after expansion			1	6.2
8	45-degree, from the top - after expansion	1	6.2	2	12.5
9	60-degree, from the top - without expansion	1	6.2		
10	60-degree, from the top - after expansion without respecting the ratio of 1.5 between the increase in diameter and the length of the duct	1	6.2	1	6.2
11	Unknown	1	6.2		
12	Total	16	100	16	100

Elbow type and R/D ratio: The results of the type and the number of elbows in the design and its existing status are presented in Table 8. In addition to the items mentioned in this table, it can be emphasized that three elbows have been removed totally**.** Only 6 out of 75 cases between the design and status quo had the compliance and the conformity. In design and the status quo, 4 elbows (5.3%) had an R/D ratio of 1 and the rest (94.7%) had an R/D of 1.5. The maximum percentages of elbow in the present situation were achieved by one piece (stamped) 90-degree elbow with 33.37%, while the minimum percentages of elbow were 90- and 45-degree elbows with multi-piece and R/D=1. The maximum percentage in the design is 90-degree one-piece at 40% and the minimum is 90-degree multi-piece elbows with R/D=1.

Table 8. Number of elbows in design and existing

Elbow type	Design		Existing	
	No. (#)	Percentage %	No. (#)	Percentage %
30-degree, Multi pieces-R/D=1.5	3	4	1	1.3
45-degree, Multi pieces-R/D=1.5	5	6.7	4	5.3
60-degree, Multi pieces-R/D=1.5	2	2.7	0	0
90-degree, Multi pieces-R/D=1.5	12	16	13	17.3
30-degree, Stamped-R/D=1.5	2	2.7	2	2.7
90-degree, Stamped-R/D=1.5	33	44	28	37.3
45-degree, Stamped-R/D=1.5	14	18.7	18	24
90-degree, Multi pieces-R/D=1	3	4	3	4
45-degree, Multi pieces-R/D=1	1	1.3	1	1.3
Removed	0	0	3	2.7
Total	75	100	75	100

Discussion

All components of the system were installed permanently, accurately, appropriately, and securely on supports that had sufficient capacity to bear the weight of the system. No vibration or No sound occurred due to the Lack of strength and unstability of the ducting structure. The investigation of the number of ducting supports did not find a significant difference between design and existing status.

For easy repairs (cleaning, assembly, and disassembly), the system is required to use flanges at certain points[18]. The Mann-Whitney results showed a significant difference between the number of flanges in the design and the present status (P-value=0.002). The reason for reducing the number of flanges in status quo to the design and drawing document can be attributed to their removal by users or installer technicians over time, which will create problems for system repairs.

According to scientific recommendations, the horizontal ducting at systems with heavy dusting, especially near elbows and connecting points, have to be equipped with cleanout doors[18, 29]. There was no significant difference between the number of cleanout doors in the design and the cleanout doors at status quo. However, a significant difference emerged between the number of designed with standard and the number of status quo with the standard (in both P-value=0.00). According to the results, the reason for the increasing number of cleanout doors in the existing status than in the drawing is users' need and installation at time lapse. In other words, the weakness in system performance may cause particles to settle in the ducts and require frequent cleaning. This cleaning is possible by installing multiple cleanout doors or by the installer adding them during operation and installation (Figure 3). It is also recommended that the cleanout doors be installed on the upper half of the duct horizontal turns and close to the couplings, joints, elbow and vertical turns. As the results of the tests show that the valves installed are in the appropriate place[18, 29, 30].

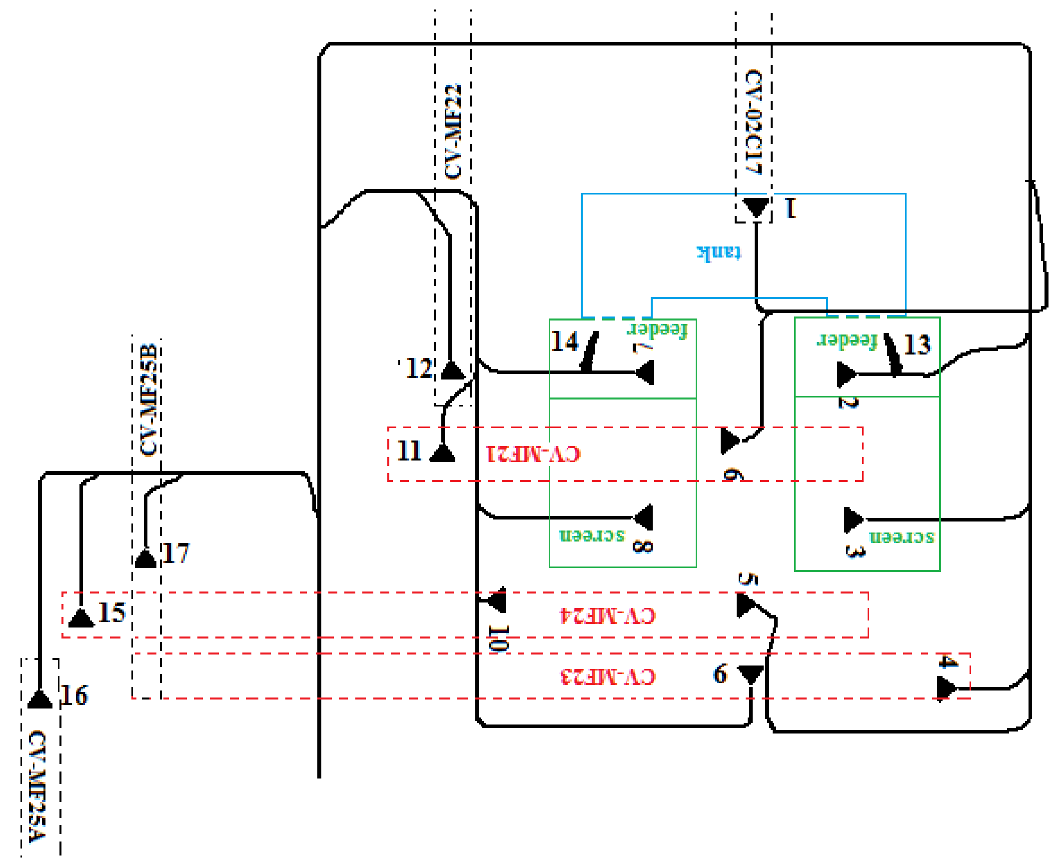


Figure 3. The cleanout door that is not included in the drawings but seen in the status quo

For proper monitoring and operation, it must be installed in different parts of the system, air flow or pressure displays, and these monitors should be equipped with three way valve for cleaning cleats[18, 29]. Due to the lack of a three-way system, it is not possible to monitor and maintain the system from them. In order to adjust the velocity and airflow in the ducts, the branches must be equipped with a damper. Due to the locking of the embedded damper, these conditions are not possible.

According to the scientific resources' recommendations, the sub-branches should be located at the gradual expansion to the main duct at an angle less than of 45-degrees, preferably 30-degrees. Also, this connection must be from above or the side of the main duct and connected to each other directly[18, 31, 32]. Considering that in 87.5% of cases in executive drawings, the angles of the branches were 45-degrees, the designers was aware of the effect of the branching angle in the air turbulence, the pressure drop, and obstruction in the branch. Therefore, they tried to apply the recommended angle of 45-degrees. However, at the status quo is not met and be deteriorated. The number of branches with a 45-degree angle from 87.5% in design to 68.75% in the present state has decreased and, on the contrary, the amount few of branching's with a 60-degree angle has increased. The reason for this can be attributed to the change made by the installer or the insouciance of design drawings by the repair and maintenance agents of the system over time. No branching with a 30-degree angle has been used in any of the existing status and design drawings. This may be due to the habit of installing teams at 45-degrees or miter joint on implementation. The combination of 45-45-degrees among executive teams is more common than the 30-60 combinations.

Approximately 25% of the branches have changed from the installation and executable drawings. These changes are not documented based on the change management process. These changes can be attributed to the time of the initial installation of the installation and execution drawings, and the passage of time. These changes cause Unbalances, clogging from of Unbalance, and system performance degradation.

The results of comparing the joining point (site) of branches input to the duct in the existing status and the drawings documents indicate that there has been no significant change. In 87.5% of cases of the joining point of branches input to the duct, the installation principles (up and side joining) are observed. There was no agreement in the manner of joining branches in three of the 16 cases between the design drawings and the existing status. According to the resource recommendation, the best mode for joining the branch input to the main duct is the input in the expansion. The results indicate that this issue has not been met in any of the input cases. On the other hand, in the design for balancing the system, in 75% of the cases, the diameter be increased after the branch joining to main duct (and did not have a 25% increase in diameter). While in the current situation, however, this has dropped by 50%. In other words, along with increasing the needed airflow, the diameter of the duct has not increased and has led to an increase in duct velocity. This situation may indicate a lack of knowledge or mis-attention in terms of installers, repairers, managers, and system users.

Usually in LEVS, due to the flow velocity and the dimensions of the ducts used, the air flow is usually turbulent and disturbed. The phenomenon that occurs at the site of the transition is usually the separation of the boundary layer (Vena Contracta), which increases the turbulence and decreases the operational diameter of the ducting, as a result increases its velocity and also increases erosion, especially on the elbow. Therefore, according to resources recommendations, the thickness of the elbows and bends should be at least 2-degrees greater than the thickness of straight ducts of the same diameter[18].

Since the elbows and ducts material are effective wear-resistance factors, the materials must be made to last a lifetime. Test results indicate that this effect is greater in the elbows than in the branches and expansions. because typically incremental transition and branches occur along with increasing diameters, therefor air flow passes straightly through the duct path. As such, there is no intense flow contact with the duct. In these conditions, it may not be necessary to increase the thickness of the sheet. However, in the elbows and contractions, because the flow contact with the duct body is intensified, it is imperative to monitor and adjust the thickness. As result, in total, thicknesses equal to or greater than 2-degrees accounted for 95% of the cases. Because of the air turbulence and wear (erosion) in the elbows, more attention is paid to these components. Beyond the elbows in the branches, air turbulence is more obvious, but they are no thicker in any. In the drawings design of the expansions, these factors were not optimal, being less than 52% of the desired thickness. Perhaps it has been considered that in loose conditions, the risk of wear is lower than in straight ducts, because the flow has a smaller diameter than that of the duct.

With respect to standard DIN 17006, in elbows (multiple pieces), branches and transition that tolerance and experience more turbulent and wear, st-37 have been used and are more robust; otherwise, single-piece elbows of st-35 are used. In other words, for one-piece elbows, except for 2 of the 51 cases (for 96%), st-35 is used.

Of the 75 elbows used, none met the recommended R/D ratio. We know that it is necessary to evaluate the peripheral conditions when choosing an R/D ratio for an elbow, and, in those situations, an elbow with a higher R/D ratio is selected (2 and preferably 2.5). However, these results and conditions indicate that this issue has not been taken into consideration[18, 22]. We found here to have been no adaptation of the intended elbows drawing design to the existing situation. The main reason for this may be the type of selection and installation by the technician at runtime, based on the conditions at hand.

In the ventilation system, the duct geometry was implemented according to resource recommendations[18, 29] and the surveys indicated the use of circular geometry in all the ductwork.

One of the principles underlying the design of LEV systems is the selection of the shortest route and minimum number of elbows in the ductwork[18, 29]. The results show that in seven cases (47%) of the hoods of the studied system (hoods No. 1, 2, 5, 6, 9, 11, 12), the ductwork route was inappropriate and in the remaining eight cases (53%), the route was suitable. Further assessment is needed to correct these inconsistencies. Sample of inappropriate connection of branching down showed in Figure 4.

Figure 4. Inappropriate connection of branching down

In the visual inspection of the system, the installation of inspection hatches and holes in the system components is necessary[18, 29]. Throughout the system, however, we found only one inspection hole, which is fitted to the hood 12 before the branch.

In a study by Aghababaei entitled Statistical Survey of the Quality of LEV Systems of Industries of Tehran, conducted during the years 2005–2009 on the LEV systems in Tehran and its suburbs. one hundred large, medium, and small industrial and service companies were studied, and the author determined with a confidence coefficient of 99% that 99% of the existing systems had structural defects. The reason for this was the use of traditional firms in the marketplace rather than qualified experts. This, in turn, is due to the lack of legal requirements established by the authorities and the inability of the inspectors to report defects, which ultimately negatively affects the health of the workplace[33]. The results of the current research also show that there are some design defects, each of which was specifically discussed. However, we emphasize that the system we studied was designed and installed by a foreign and experienced contractor in the 1988s, and complies with some design standard minima, as compared with some of the other existing systems in the same company.

The published articles on change management discuss the various steps that must be taken into account during change product and process changes are considered[7, 14, 15]. This is despite the fact that such steps have not been dominant when considering ventilation systems. One of the shortcomings of the solutions presented in the change management processes is the tracking of change. In order to solve this problem, scholars have investigated several innovative and practical solutions that might be adopted and applied by industry[5-7]. According to Hao et al., one of the concerns of the change management process involves defects in the ability to track process changes. This was also evident in tracking changes in ventilation systems. The Hao et al. study found that there is a need to develop an innovative solution that can be adopted by industries[7]. The method presented in this study uses a comparison of standard, design, and existing status, which can be identified and tracked by observing any discrepancy between design and existing status.

Change management is a complex process that needs to be followed by a path and flowchart for any change, and any changes to these documents must be entered. Updating documents is an integral part of the change management process[15]. There was no change or updating of the documentation regarding the changes in the ductwork of the ventilation system under study. The model presented in this study, in addition to providing refined points for future design, can be considered for updating documents that have not traditionally been considered as part of the change management process.

In his study, Pikosz explains the main purpose of the change management process as including information in documents. Documents are stored in various archives or computer systems. The dimensions of the process show how different aspects interact or must interact with various processes. By communicating between different aspects, any inconsistencies between the process and access to systems or information can be discovered[34]. One of the basics of the method presented in this study was the same. By comparing the existing status of the system, drawings and comparisons with standards, points of conflict, or deviations from the standard were identified.

After studying the steel industry, Toit argued that change management could be effectively used to mitigate and reduce the effect of uncontrolled changes by large steel companies[35]. Uncontrolled changes, such as system imbalances due to the false installation or incorrect alteration of ducting components, can lead to system degradation or inefficiency. Due to the high variations in the lifetime of the ventilation system and its inefficiency, this need exists[36, 37].

In a study conducted by Riviere et al., considerable effort was made to better understand the relationship between change management and improving the quality of complex products. One of the important steps in the change management process was the updating of documents. Riviere et al. introduced and applied several indicators for each step. They stating that the productivity indicators were based on the evidences and documents affected by the change and those who were informed of the new solution[15]. Changing the components of the ventilation system will cause imbalance between of the branches and reduce the system's efficiency with regard to maintenance and power consumption costs. If the drawings, documents, and the system itself can be updated with standards-based revisions, they can increase productivity that more compensates for payment costs incurred by maintenance and use of the system.

Quintana et al., In their study, introduced a new approach to change management that called the Reengineering Change Management Process for condition without drawing. The proposed approach was a defining model. This non-design environment offers a solution to the needs of downstream users over the lifetime of a product[14]. The present study with use of provided checklist by different way uses of definitions to change management.

Pikosz and colleagues stated that support for change management using computers was low in the companies they studied. The reasons for this included the large size of certain buildings, the use of multiple buildings, and the various computer tools that needed to be integrated. They stated that in the old systems, considerable data are gathered that cannot support the change in detail. But all the companies performed activities to create a basis for further management of product data that would manage future engineering change[34]. The method proposed in the present study can be helpful in this regard. In the LEV system under consideration, the first step was not successful in updating drawings and documents (even in the old way). Considering the results of the Pikosz study, the use of computer support for managing change systems, products and equipment similar to the LEV system of the present study will be useful, but the process is not easy to accomplish without design.

Conclusion

The evaluation of the duct components revealed discrepancies between the existing system, design drawings, and recommended ventilation standards. While the minimum structural ventilation requirements were generally met, certain parameters, such as elbow ratios, did not fully comply. This highlights the necessity for skilled personnel and thorough review during the implementation of systems delivered by external companies.

The applied methodology—a combination of visual inspection and standards-based questionnaires—proved effective in identifying non-compliance and inconsistencies across the existing system, drawings, and standard documents. This approach can serve as a practical tool for change management, updating documentation, identifying potential deficiencies, and monitoring improvements in industrial ventilation systems.

It is recommended that future studies weight duct design parameters according to their relative importance to enable more precise identification of potential issues. Furthermore, implementing a digital tool for recording and monitoring changes could enhance standard compliance and support continuous system improvement.

Ethical Considerations

None.

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Conflict of Interest

None.

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References

1. Gillies A, Wu HW. A comparison of air leakage prediction techniques for auxiliary ventilation ducting systems. 1999.

2. Heinsohn RJ. Industrial ventilation. J. Wiley; 1991.

3. Jackson R. Monitoring Local Exhaust Ventilation Systems. The Annals of occupational hygiene 1976;19(3-4):309-312. doi: 10.1093/annhyg/19.3-4.309

4. Monitoring and Testing of Ventilation Systems Industrial Ventilation: A Manual of Recommended Practice. 24th, editor. ohio Cincinnati: ACGIH; 2001.

5. Al-Mashari M, Zairi M. BPR implementation process: an analysis of key success and failure factors. Business process management journal 1999;5(1):87-112. doi: 10.1108/14637159910249108

6. Huang G, Mak K. Current practices of engineering change management in UK manufacturing industries. International Journal of Operations & Production Management 1999;19(1):21-37. doi: 10.1108/01443579910244205

7. Hao Q, Shen W, Neelamkavil J, Thomas R. Change management in construction projects. 2008:

8. GHARAEE MA. Change management and change process model for the Iranian construction industry. 2012.

9. Dhimmar VN, Sharma ND, Rathod MHA. Evaluation factors influencing change management for construction project.

10. Padala SS, Maheswari JU, Hirani H. Identification and classification of change causes and effects in construction projects. International Journal of Construction Management 2020:1-20.

11. Jayatilleke S, Lai R. A systematic review of requirements change management. Information and Software Technology 2018;93:163-185. doi: 10.1016/j.infsof.2017.09.004

12. Jarratt T, Eckert CM, Caldwell NH, Clarkson PJ. Engineering change: an overview and perspective on the literature. Research in engineering design 2011;22(2):103-124. doi: 10.1007/s00163-010-0097-y

13. Hamraz B, Caldwell NH, Clarkson PJ. A holistic categorization framework for literature on engineering change management. Systems Engineering 2013;16(4):473-505. doi: 10.1002/sys.21244

14. Quintana V, Rivest L, Pellerin R, Kheddouci F. Re-engineering the Engineering Change Management process for a drawing-less environment. Computers in Industry 2012;63(1):79-90. doi: 10.1016/j.compind.2011.10.003

15. Riviere A, DaCunha C, Tollenaere M. Performances in engineering changes management. Recent advances in integrated design and manufacturing in mechanical engineering. Springer; 2003:369-378. doi: 10.1007/978-94-017-0161-7_36

16. Ullah I, Tang D, Yin L. Engineering product and process design changes: a literature overview. Procedia CIRP 2016;56:25-33. doi: 10.1016/j.procir.2016.10.010

17. Makarainen M. Software change management processes in the development of embedded software. VTT PUBLICATIONS 2000;4(1):6.

18. Greenberg MI. Occupational, industrial, and environmental toxicology. Elsevier Health Sciences; 2003.

19. Said MR, Hasan NH, Leman A, Abd Rahman M. Baseline Inspection and Measurement of Local Exhaust Ventilation (LEV) Systems at Spray Booth in Manufacturing Plant. The Journal of Selcuk University Natural and Applied Science 2013;(Specia):637-647.

20. Szklarzyk P. Visual inspection as one of the important elements of the quality control. Production Engineering Archives 2014;2. doi: 10.30657/pea.2014.02.03

21. Abedi K, Rastani MJ, Dana K. Innovations and future directions in hybrid non-thermal plasma-catalyst systems for VOC decomposition. Chemical Engineering Journal Advances 2025:100882. doi: 10.1016/j.ceja.2025.100882

22. Guide Lines on Occupational Safety and Health for Design, Inspection, Testing and Examination of Local Exhaust Ventilation System. Malaysia Doosahmohr; 2008.

23. Maintenance, examination and testing of local exhaust ventilation. Health and Safety Executive; 2004.

24. Stern AC. Fundamentals of air pollution. Elsevier; 2014.

25. Goodfellow HD. Industrial ventilation design guidebook. Academic press; 2001.

26. Burgess WA, Ellenbecker MJ, Treitman RD. Ventilation for control of the work environment. John Wiley & Sons; 2004. doi: 10.1002/0471667056

27. Local Exhaust Ventilation (LEV) Guidance: The Health & Safety Authority; 2014

28. Rose CJ. Ventilation Duct Inspection [Available from: https://ezinearticles.com/?Ventilation-Duct-Inspection&id=2853588]

29. Guyer JP, P.E. RA. Introduction to Design of Industrial Ventilation Systems. Continuing Education and Development, Inc., 2009 Contract No.: D02-001.

30. Industrial Ventilation-A Manual of Recommended Practice. 24th, editor. Cincinnati, Ohio: ACGIH; 2001.

31. Assessing and inspecting Local Exhaust Ventilation (LEV) systems Disease Reduction Programme Health & Safety Executive; 2009.

32. Raleigh, editor Raleigh, editor. Monitoring & Maintenance of Ventilation Systems. 52nd North Carolina Industrial Ventilation Conference; 2010.

33. Aghababaei M. Statistical analysis of the quality of local exhaust ventilation systems industries Tehran. 2nd national industrial ventilation & hygiene conference (Persian)March, 2011.

34. Pikosz P, Malmqvist J. A comparative study of engineering change management in three Swedish engineering companies. 1998:78-85. doi: 10.1115/DETC98/EIM-5684

35. Du Toit D. Engineering change management in a large steel manufacturing company 2014.

36. Jamshidi Rastani M, Ghorbani Shahna F, Bahrami A, Hosseini S. Evaluation of local exhaust ventilation system performance for control of Fe_2O_3 dust at an iron making unit. Health and Safety at Work 2016;6(2):43-56.

37. Jamshidi RM, Farshid GS, Bahrami A, Hosseini S. Evaluation of local exhaust ventilation efficiency to control emissions of fe2o3 dust in ambient air of the oxide screen unit in steel industry. 2015.