OSH 00542-B
00080690

TECHNICAL CRITIQUE OF RECIRCULATION OF INDUSTRIAL EXHAUST AIR CRITERIA

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To critique is to judge that which is worthy of praise as well as to point out limitations. The subject report, "Guidelines for the Recirculation of Industrial Exhaust Air," submitted by Arthur D. Little, Inc., to NIOSH under Contract No. 210-76-0129 (ref. 1), is praiseworthy in many ways. However, when judged from a practical standpoint, it also has several limitations.

The report presents a logical framework for judging the impact on worker safety if exhaust air is recirculated. In this respect, it is certainly an improvement over the report "Development of Criteria for the Recirculation of Exhaust Air" (ref. 2) submitted previously to NIOSH. Few of the considerations for judging the impact of recirculation are original with the subject report. Most have been mentioned previously (ref. 3) or would become self-evident in the planning of a recirculation system. It is, however, the completeness or thoroughness of the present report which is praiseworthy.

The central theme of the subject report is worker safety. This is reasonable since worker safety is a constraint which must be addressed in all recirculation systems. The resulting guidelines are very useful to occupational health personnel for determining the feasibility of recirculation from a health standpoint. The suggestions concerning performance validation, emergency planning, maintenance, and written operating procedures are particularly important reminders that health professionals must be involved at stages beyond feasibility approval. Guidance for the continued assurance of worker safety is the strength of the subject report.

The authors from A. D. Little are careful to point out that the report is not intended as a detailed design manual for recirculation systems. They do, however, occasionally venture away from the central theme of worker safety to present guidelines for selecting equipment or determining the economic feasibility of a recirculation system. These digressions are of limited usefulness to occupational health personnel. Also, because the guidelines in these areas are not fully developed and reference sources are not provided, the report is of limited value to the engineer concerned with design, equipment selection, or economic feasibility. As an example, additional physical and chemical properties that would be important for design and equipment selection, but are not mentioned in chapter 3, are sorbability, electrical or sonic properties,

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hygroscopicity, agglomerating characteristics, and the potential to poison catalytic converters. A title more representative of the contents of the report might be "Guidelines for Assuring Worker Safety in the Recirculation of Exhaust Air."

In making this commentary on the report I realize that its central purpose was worker safety. It is of value, I think, to point out that this is a limitation of the report itself. When I considered this, one of the questions that came to my mind is, if there were only one copy, where should that copy of the report be located in an industry like ours where there are industrial hygienists and ventilation design engineers. My feeling is that it should very definitely be located in the occupational health professional's office rather than in the design engineer's office. It will be much more useful to him than it will be to the design engineer. It is the type of document that an industrial hygienist might, with some sadistic glee, hand to an engineer who dares to propose recirculation, pointing out all of the health implications to be considered and that are contained in the document, and suggesting to the engineer that he return when he has read the document and understands it. To reiterate, the report is very useful to occupational health personnel in assessing recirculation plans, but it does not provide sufficiently detailed guidance to be helpful to engineers concerned with practical design or economic feasibility. Practical guidance for air cleaner selection is contained in the Air Pollution Manual: Part II from the American Industrial Hygiene Association (ref. 4), and for the economic feasibility of recirculation in a 1951 publication from the New York Department of Labor (ref. 5).

The normal way to approach the modeling of an exhaust recirculation system is through a material balance--input minus removal equals accumulation. Equations depicting the rates of input, removal, and accumulation are integrated between zero and infinite time. The resulting steady-state equations are generally solved for contaminant concentration in the general workroom. Input parameters for those equations that are difficult to measure or must be estimated are the contaminant generation rate, the hood capture efficiency, and the air mixing factor. It is also difficult to relate the general workroom concentration to that which the worker actually breathes.

The authors of the subject report have presented a different mathematical model. As developed in chapter 5 and appendixes A, B, and C, the model is the most unique contribution of the report. The objective of the model is to calculate the contaminant concentration of the recirculated air, C_R, and then relate this to the worker's breathing zone concentration, C_{BZ}. The model attempts to address the question of measurability of input parameters, which has been cited as the major shortcoming of previous mathematical models describing recirculation.

It is interesting to note that the abstract of the previous NIOSH symposium on exhaust air recirculation (ref. 6) concluded that "designing of new systems, where possible, is preferable to remodeling or adding on." This is in direct contrast to the present report which states that "generally it is easier to design recirculation systems for retrofitting." This difference of opinion seems partly attributable to the two different mathematical models being considered.

Because it emphasizes the measurability of input parameters, the A. D. Little model is probably more applicable to existing local exhaust systems where the concentration of contaminant in the local exhaust duct, C_E, can be measured. Measuring this concentration precludes the need for estimating the contaminant generation rate and hood capture efficiency used in the previous model. If, however, the duct concentration cannot be measured, as in a new system, the A. D. Little model is no better than the previous model in terms of input parameters. In fact, because it requires the estimation of two additional factors, k_R and k_{BZ}, as opposed to one, the mixing factor for the previous model, the A. D. Little model may be less desirable for new systems. Clearly, for existing local exhaust systems, the model proposed in the subject report is superior. If for no other reason, this is true because it is more fully developed and integrated into a plan for contaminant monitoring and system failure.

Regardless of the model used, one of the more crucial input parameters is the initial concentration of the contaminant in the breathing zone of the worker, C^o_{BZ}. Likewise, the ultimate performance validation of the installed system depends upon reliably measuring the worker's exposure to the contaminant (determining C_{BZ} actual). The guidelines presented in appendix A regarding these parameters are useful. However, reference should be made to recent NIOSH publications on exposure sampling strategy (refs. 7 and 8) as guidelines for improving the reliability of these crucial measurements.

It is stated in the report that for recirculation to be feasible, "the ideal situation would involve an existing ventilation system in which exhaust air is currently being cleaned to comply with EPA regulations." For several reasons, this statement is more correct than the authors may realize. First, EPA regulations limiting the emission of contaminants would provide additional justification for recirculation beyond the energy-saving incentive normally present. Second, our experience at economically removing contaminants from an airstream is greater for chemicals that are regulated by the EPA. Third, automated monitoring systems for specific chemical contaminants are much further developed for those materials now regulated by EPA than for materials that EPA has not addressed.

The report on recirculation submitted by the Southwest Research Institute to NIOSH (ref. 2) addressed the latter two considerations by trying to determine if there are monitors or air cleaners available for specific contaminants. This is important because the availability of contaminant monitoring systems is probably the most serious impediment to "safe" recirculation. Few recirculation systems will be designed that depend upon repeated manual monitoring. If the contaminants are nuisance materials, little monitoring will be done, unless there are complaints. If the contaminants are toxic, then workers, health professionals, and supervisors feel safer with an automatic monitoring system. The guidelines provided by the A. D. Little report are quite reasonable. Perhaps they will stimulate experiments with the recirculation of contaminants for which automatic monitors are not available. Refinement of the concept of a critical response through experimentation is necessary.

Another comment which must be made about the A. D. Little report is one of form rather than content. The authors suggest that ultimately there is no choice but to read and understand the material presented in the appendixes, especially the development of the model. This is a monumental undertaking. The appendixes are equally as long as the main text with far more complexity. The initial system for which the model is developed in appendix A is far too complex to allow gradual development. The reader is immersed in symbols and equations. Only the most dedicated readers will continue through the maze.

It seems that a more desirable approach would have been to start with a simple system such as with one local exhaust, and introduce more complex elements singularly. The value of the report is sufficiently great that it would be a shame to reduce the comprehending audience by unnecessary initial complexity.

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DISCUSSION

CHAIRMAN HUGHES: We would like to open the floor for questions at this point, either for Bill Dyson, Scott Stricoff, or John Hagopian.

MR. BILL HALL (Quaker Oats Company, Chicago, Illinois): Are we going to touch on levels of nontoxic dusts that might be permitted in the atmospheres, and are there any known standards by which environmental air may be measured by the plant to determine if the hazard of a dust explosion exists?

MR. STRICOFF: As far as nontoxic or nuisance particulates are concerned, we have, in several places throughout our report, used that case as a specific exception to some of the guidelines that generally apply to the recirculation of toxic materials. Specifically, monitoring requirements where you're dealing with nuisance or nontoxic particulates, and nothing else, are far less critical than monitoring system requirements when one is dealing with toxic materials. As far as the specific levels are concerned, there is, of course, an OSHA standard, as well as a TLV, for uses of nontoxic dusts, and those are legal recommended requirements, airborne levels for worker safety and health.

As far as the explosive dust aspect is concerned, there has been experimental work done to determine the minimum explosive concentrations of different kinds of dust. That research tends not to find its way into the industrial health literature, although it is in fire research literature. There is no method that I'm familiar with for providing an online mechanism for monitoring the explosive concentration of the dust, but the explosive concentration of the dust can be determined from the literature. You can design systems so as to preclude explosive levels and then use a monitoring approach, just looking for changes, assuming that when your system is operating normally you don't have the explosive dust problem.

MR. PHELPS ESHELMAN (General Motors, Warren, Michigan): I have a two-part question for the representatives of Arthur D. Little. In your report that you submitted to us, you talked about air cleaning devices only on systems. Did you take a look at the units that are running in the building with no ductwork attached to them, and why are you penalizing systems which have ductwork, saying that they must be monitored and not the other ones?

The second part of my question is this: Also in the report you are referring to monitoring of this return air being sent back to the buildings. Do you know of something that will continuously monitor this besides this magic black box you have, and why wasn't more consideration given to area sampling or personal sampling to determine the quality of the air that is being recirculated?

MR. STRICOFF: To answer the second part of your question first, the problem that we have conceptually with using area sampling and personal sampling for evaluating the efficiency of recirculation systems is the time problem that one faces. Looking at the rise time that is normally associated with recirculation system failures, you find that, once there is a failure, you may see rapid and massive increases in toxic level concentrations in the workplace, and relying on personal sampling and area sampling can get you into trouble. Now what we've said is that this should be evaluated, that you should look at what the rise time in fact would be in a particular situation, and if the rise time is sufficiently slow that you can use personal or air sampling, there is nothing wrong with it.

To answer the first part of your question, we, I believe, allowed for that. The "hanging on the ceiling" kind of recirculating system is, as far as one might determine, an area system, and if it was hanging in a room where there were toxic materials and you were relying on it to maintain control over the levels of toxic materials in the room, then it should be evaluated in accordance with the same criteria that apply in more complex systems. Whether that is reasonable or not, I have trouble saying at this point.

The other thing I should have said about that is that monitoring can be very simple depending on how you approach it, and it doesn't, in all cases, require analytical chemistry. Monitoring systems that under some circumstances, some unique circumstances, might be acceptable, could be such things as power failure or circuit breaker indicator, something like that. It really depends on the situation. Where you want to be able to tell when the system has stopped working, and you can do that without getting into carrying little chemistry kits, so much the better.

MR. JEFF GREEN (Kohler Co., Kohler, Wisconsin): Getting back to the question about the monitoring equipment, are you aware of any criteria or equipment used to monitor clean air or return air? I have a problem right now--I'm trying to recirculate some air which is carrying lead dust and trying to find equipment to do that is very difficult.

MR. STRICOFF: The underlying concept of our particular work on monitoring, in our estimation, is that we haven't said a lot of very specific things about monitors and air cleaners, in contrast to the report that Southwest Research Institute did for NIOSH a few years ago. The reason for that is that we felt it was not the most appropriate way to allocate resources that were available. The situation with monitoring and air cleaning is a dynamic one. To take a "snapshot" view of what is available in terms of equipment now is a lot of effort, and if we attempted to do it, by the time we got the work finished it would probably be out of date. Instead, what we tried to do is provide some guidance that really amounts to telling someone what sort of performance requirements should apply to monitoring an air cleaner that is intended for air recirculation systems. If you are going to use an air cleaner you should do certain things. If you are going to use a monitoring system it should perform in certain ways, and what specific kinds of hardware, or even kinds of technology you use to meet those performance requirements is something that is really beyond the consideration--we felt it was one step beyond what we were trying to accomplish.

MR. HAGOPIAN: We also say that unavailability of a monitoring system in cases where there is justified need for one could be cause for concluding that recirculation is not feasible.

DR. DYSON: For your specific problem, the upcoming OSHA standards on lead might completely resolve that for you, since I think they are considering the possibility of prohibiting recirculation of exhaust.

MR. LOUIS DICKIE (DCE Vokes, Jeffersontown, Kentucky): I want to carry the line Phelps Eshelman was on a bit farther, and maybe this is going to be more editorial than question.

I was excited when you began this morning, Bob, with the fact that energy conservation is mandatory and recirculation was a means of doing that. I was a bit disappointed when just a few sentences later you said that this report was neither to encourage nor discourage recirculation. I was even more disappointed with the A. D. Little report, which I think discourages recirculation. It discourages it through what it doesn't say.

One of the speakers mentioned briefly that there is an assumption that all the other ventilation systems in the building have monitors, and that is a false assumption. They do not. The considerable emphasis that this report places on modes of failure and monitors to determine these failures of recirculation systems leaves the impression that this is the only risk involved in a plant. The risk is there without the recirculation if you have failures of the other ventilation systems.

In my mind, the monitor is in the wrong place if it is in the recirculation system. It should be where it measures the air the worker breathes, because the quality of that air is affected by every piece of ventilation in the plant.

I think that in publishing this report, and I can realize A. D. Little's scope was to evaluate recirculation systems, there has to be some sort of preface. It says these safety measures belong to the entire ventilation system any time there are health hazards involved.

Maybe you would want to comment on that, Bob, because I guess that preface is coming from NIOSH.

CHAIRMAN HUGHES: We had a previous discussion on the location of the monitor, as I recall. One thought, and I think maybe Scott and John would want to address this to some degree, is that with the recirculation system you do have a lot of the same problems that you would with a normal ventilation system. If the fan stops working or there is some kind of clogging or blockage to the exhaust, you would have a problem.

The thing that the recirculation system does that the normal exhaust system does not, is that rather than taking that air that has gone through a cleaner and discharging it outside, hopefully in a manner which doesn't reintroduce it, you're introducing that air directly back into the workplace. Any kind of a failure with the air cleaner could create quite the same situation.

Insofar as the method of monitoring, I think that proper procedure for monitoring various situations of recirculation could have almost infinite variations. In some cases it may be required to have very sophisticated monitoring, and in some cases only as much as visually looking at the return and seeing dust particles coming out. Evaluating each individual situation has to be done in a manner which is consistent with that particular system. I don't think there is any other way to say it. Whether the monitor is in the duct or on the worker has to be based on an evaluation of each individual case. I would think that a monitor in a duct discharge is ideal. If that system fails you'll have immediate knowledge of it. If you have combinations of recirculating systems and nonrecirculating systems, yes, the interaction of those systems is going to affect the workplace. In some way you have to monitor the recirculating system. If you have the monitor on the worker, or you're taking a worker sample and the nonrecirculating system fails, you don't know where the failure is.

The worker protection is important, and I think it has to be viewed on an individual basis.

MR. DICKIE: You said you have to have a monitor on the recirculation system, and this puts the stick on recirculation systems as being less safe than other types of ventilation, and that is going to discourage the installation. It puts a penalty on them in the cost standpoint.

Now you can take the same air cleaner, that exhaust-cleaned air outside the building, and that air cleaner can fail and leave the contaminants in the building; but nobody says it needs to be monitored, particularly the fabric collector. The general failure is one of high pressure drop, loss of air, but all of the emphasis is put on the fact that the danger is in recirculating the air, not that it is in other types of failure. I'm not saying there should be no monitor. I'm merely saying monitoring one piece of the total system, specifically recirculation of the local exhaust hood as opposed to space cleaners, is going to put a penalty on recirculation that will cause people not to consider it. The thing that should be monitored is the atmosphere that can be unhealthy to the worker, not performance of a piece of equipment.

CHAIRMAN HUGHES: I believe that any properly operated plant should definitely have a monitoring system to assure that all of the systems are working properly. You would not just monitor the recirculation system alone and ignore the others. I think that by directing the air . . . .

MR. DICKIE: You've answered my question. We both have the same belief. I'm just afraid that the report, to the hundreds of thousands of people that don't have the experience that is in this room, is going to attach a statement of recirculation that will cause them to ignore it, whereas they should have the same types of controls and monitors on their general ventilation, their makeup air, their exhaust, and everything else. That has to be said somewhere or we are going to penalize recirculation of the local exhaust systems to the point that they won't be useful.

CHAIRMAN HUGHES: I think a clarification of that is in order, yes.

MR. JOHN TALTY (NIOSH, Cincinnati, Ohio): I wanted to ask if John or Scott would comment on the statement that was made that the Arthur D. Little report results would either not be able to be used or would in fact not be used by design engineers who would be designing a recirculation system. I think that was most unfortunate.

MR. HAGOPIAN: As you know, we've developed an analytical approach by which design engineers can arrive at general system performance specifications which are optimum for a particular plant area being investigated. It is not going to help them design the hardware, that's true, but it serves the purpose of defining what various flow volumes must be and generally how air should be distributed throughout the workplace. I really don't know what more to say than that. I would like to think that it provides all of the basic information needed for a design engineer.

MR. STRICOFF: To add to that, while it is true the report does contain a fair amount of information that is probably not of interest to the design engineers, I think it also contains a fair amount of information that is not particularly of interest to industrial hygienists. It is mainly aimed at a full audience. Recirculation isn't something that should be undertaken by a design engineer or industrial hygienist. It is something that should be undertaken by both, and it requires input by both, and cooperative effort by both, and to that end the report is intended to speak to both, and we would hope it would be used that way.

CHAIRMAN HUGHES: With regard to one of Mr. Dickie's original comments on my statement that we were neither encouraging nor discouraging recirculation, I think that was a bad choice of words. What I'm really trying to say is that NIOSH is taking the approach that we want to develop guidelines or criteria, whatever we may call it, to assist people in understanding what the problems may be and how to approach them so that worker health will be considered. We are trying to encourage energy conservation, but our purpose here is to be sure that health is protected.

The other thing I might mention with respect to monitoring and our original intent is that there needs to be some kind of a monitoring device, system, or technique, to assure that the recirculation system, in conjunction with the rest of the ventilation system, is not going to cause a problem. In many cases it is going to be difficult to find the proper equipment, because this type of equipment has not been in demand in the past.

MR. STRICOFF: I don't know if you're familiar with it, but in our draft report we point out and accept with no hesitation the fact that monitoring can be done either in ducts or in workspace. Also, it can be done either manually or automatically, and similarly, it can either be done with contaminant or nonspecific approaches, and we don't pass judgment on any of those approaches. All we've attempted to do is get people to recognize that there are differences, and recognize that there are some types of situations, because of the nature of the contaminant or because of the nature of the physical layout of the workplace and airstream, where specific kinds of monitoring approaches are not appropriate. All that we want to do is help people realize where they shouldn't be doing certain things. We are not attempting to prescribe to people what they should do, because we think that is self-defeating.

MR. ESHELMAN: I don't know if I was fortunate or unfortunate to receive a copy of your preliminary document. The question that has been asked is how can we, the people sitting here, really give an intelligent critique on it when we have not received or even see a copy of this up until today.

Now my other question, or statement, is in response to the gentleman from NIOSH. As a design engineer, I was glad to hear Bill say that he thought the document should stay in the health office, because as a design engineer, I would get discouraged trying to find the information in there that would help me design an exhaust system for recirculation. The information is there. It is in the document. It is buried. You can't find it. Maybe I'm critiquing something here which I shouldn't. Maybe the final report will bring it to light, but it is so deeply buried that as a design engineer I would get discouraged reading it and put it on the shelf or use it to hold the door open, rather than as a useful tool at the present time.

CHAIRMAN HUGHES: Your comment is well taken. We'll consider these comments in editing for the final report.

MR. JERRY FLESCH (NIOSH, Cincinnati, Ohio): I would just like to point out for the gentleman who asked about the lead problems, that I believe that recirculation has been successfully applied in firing ranges to reduce lead contaminants to acceptable levels, and I have some more information if you would like it.

THE RECIRCULATION OF INDUSTRIAL EXHAUST AIR

Symposium Proceedings

sponsored by

National Institute for Occupational Safety and Health
Cincinnati, Ohio

October 1977

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering

December 1977

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FOREWORD

These proceedings of the symposium on "The Recirculation of Industrial Exhaust Air" are submitted under Contract No. 210-77-0056 to the National Institute for Occupational Safety and Health of the U.S. Department of Health, Education, and Welfare. The symposium was held in Cincinnati, Ohio, on 6-7 October 1977.

The objective of this symposium was to discuss the development of technical criteria for the recirculation of industrial exhaust air. With emphasis on the protection of the worker's health, technical subject matter discussed included: (1) decision logic for determining recirculation feasibility; (2) design and performance guidelines for recirculation systems; (3) availability of air cleaning and monitoring systems; and (4) maintenance guidelines.

Mr. Robert T. Hughes, Chemical Agents Control Section, Control Technology Research Branch, Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Cincinnati, Ohio, was the Symposium General Chairman.

Mr. Alfred A. Amendola, Control Technology Research Branch, Division of Physical Sciences and Engineering, National Institute for Occupational Safety and Health, Cincinnati, Ohio, was the Symposium Vice-Chairman and Project Officer.

Mr. Franklin A. Ayer, Manager, Technology and Resource Management Department, Center for Technology Applications, Research Triangle Institute, Research Triangle Park, North Carolina, was the Symposium Coordinator and Compiler of the proceedings.