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Minimum Leakage/
Low Cost Duct Connections

Small Business Technology TransferProgram

Phase I Final Report

Prepared By:

Proctor Engineering Group

818 Fifth Street, Suite 208

San Rafael, CA. 94901

Principal Investigator:

John Proctor, P.E.

PROJECT SUMMARY

Technical Abstract

Leaky and disconnected joints in HVAC air distribution systems are extremely widespread. The average efficiency of duct systems in homes in the United States is approximately 55% with approximately 60% of the loss due to duct leakage. Beyond the energy and emissions penalties caused by these leaks, leaky systems have detrimental comfort, health, and safety effects. The health and safety effects include the delivery of combustion products into the homes due to leakage induced depressurization. Current duct installation practice does not attempt to address the problem.

This project developed a prototype Professionally Engineered Duct System that will virtually eliminate air leakage and that can be applied in new and replacement installations at the same labor cost as current designs. It uses snap-together duct fittings that will not come apart, can be applied to all types of duct systems, and cannot be separated without exceptional force. Its use would require minimal changes to current installation practice.

The research team developed the prototype through a multi-step process beginning with a functional analysis of duct connections. This was followed by identifying duct sealing and attachment methods offering potential to meet design objectives, evaluating the designs in terms of function and economic feasibility, and building and testing the most promising design option. Two versions of this design were developed through a test, revise, retest process. One application was to a rigid sheet metal duct, the other was to a helix core flex duct. The process produced a sheet metal application with 1/20th the leakage of a standard connection and a flex duct application with 1/10th the leakage of a standard connection. A patent search has found that the design will not infringe on existing patents and is patentable.

Anticipated Results/Commercial Applications

The Professionally Engineered Duct System can be readily incorporated into existing HVAC businesses, offering commercial opportunities to home builders, manufacturers, equipment dealers, contractors. The system can be manufactured by existing duct/sheet metal production firms and distributed by the conventional, local distribution network. It does not require any major deviation from standard transportation and warehousing activities. It can be installed by the local contractor network and by existing personnel. Its relatively easy commercialization potential offers a real opportunity to substantively reduce residential HVAC energy consumption and associated environmental impacts, while providing noticeable improvements in customer health and comfort.

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1. EXECUTIVE SUMMARY

Proctor Engineering Group (PEG), working in conjunction with Lawrence Berkeley National Laboratory, conducted Phase I of the DOE STTR Minimum Leakage/Low Cost Duct Connections project (DOE/ER-0689). The purpose of this project was to develop an innovative method of attaching and sealing duct systems that would be superior to existing methods: Performance objectives were that it should virtually eliminate leakage, provide a permanent air tight seal that does not come apart, require minimal changes to current installation practice; and have a low incremental cost.

Leaky and disconnected joints in HVAC air distribution systems are extremely widespread. The average efficiency of duct systems in homes in the United States is approximately 55% with approximately 60% of the loss due to duct leakage. Beyond the energy and emissions penalties caused by these leaks, leaky systems have detrimental comfort, health, and safety effects. The health and safety effects include the delivery of combustion products into the homes due to leakage induced depressurization. Current duct installation practice does not attempt to address the problem.

This project developed a prototype Professionally Engineered Duct System that will virtually eliminate air leakage and that can be applied in new and replacement installations at the same labor cost as current designs. It uses snap-together duct fittings that will not come apart, can be applied to all types of duct systems, and cannot be separated without exceptional force. Its use would require minimal changes to current installation practice.

The research team developed the prototype through a multi-step process beginning with a functional analysis of duct connections. This was followed by identifying duct sealing and attachment methods offering potential to meet design objectives, evaluating the designs in terms of function and economic feasibility, and building and testing the most promising design option. Two versions of this design were developed through a test, revise, retest process. One application was to a rigid sheet metal duct, the other was to a helix core flex duct. The process produced a sheet metal application with 1/20th the leakage of a standard connection and a flex duct application with 1/10th the leakage of a standard connection. A patent search has found that the design will not infringe on existing patents and is patentable.

The Professionally Engineered Duct System can be readily incorporated into existing HVAC businesses, offering commercial opportunities to home builders, manufacturers, equipment dealers, contractors. The system can be manufactured by existing duct/sheet metal production firms and distributed by the conventional, local distribution network. It does not require any major deviation from standard transportation and warehousing activities. It can be installed by the local contractor network and by existing personnel. Its relatively easy commercialization potential offers a real opportunity to substantively reduce residential HVAC energy consumption and associated environmental impacts, while providing noticeable improvements in customer health and comfort.

2. BACKGROUND

During 1997 and the first quarter of 1998, Proctor Engineering Group (PEG), working in conjunction with Lawrence Berkeley National Laboratory (LBNL), conducted Phase I of the DOE STTR Minimum Leakage/Low Cost Duct Connections project (DOE/ER-0689). The purpose of this project was to develop an innovative method of attaching and sealing duct systems that would be superior to existing methods: Performance objectives were that it should virtually eliminate air leakage, provide a permanent seal that does not come apart, require minimal changes to current installation practice; and have a low incremental cost.

Problem Statement

Low duct efficiencies are not just common, they are almost universal. Except for duct systems that are actually inside the building shell[1] distribution efficiencies range from an average 51% in existing construction (Proctor et al. 1995) to 62% range in new construction (Janski and Modera 1993).

Members of this development team have found, through studies of residential HVAC design and installation practices conducted over the past 18 years, that HVAC performance problems are largely due to the industry's failure to provide an efficient thermal distribution system, to properly install new equipment, and to properly service existing equipment. Duct systems are not designed to meet the actual load of the building, not installed to plans, and not balanced to provide design flow to each room. Performance tests that would reveal these problems are rarely performed.

Another problem is that duct installation technicians are the lowest paid and least skilled workers on a residential HVAC contractor's payroll. In areas of rapid residential growth, duct installers are commonly recruited off the street. Combined with this lack of training, contractors do not allow their workers time to put self piercing sheet metal screws into metal ducts, plastic cinch ties on flex duct connections, or follow proper taping procedure on duct board connections. While there are many methods of connecting and sealing duct systems and some--for example mastic and fiber mesh--are extremely air tight and durable, the predominant method of attachment is duct tape.

The weakest points in the delivery system are the field joints. For sheet metal systems, problems occur most often at the takeoffs, elbows, end pans and boots. For flex-duct

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[1] A design concept that is difficult to implement because soffits and spaces between floors often communicate more with outside than with inside.

systems, the splice joints and connections between sheet metal and the flex are also a problem.

Review of the Literature

Deficiencies in HVAC systems, in newly constructed homes as well as in existing installations, are pervasive and substantial. Duct leakage resulting in conditioned air dumped to outside and increased infiltration of outside air exists on virtually every home in the United States that uses duct systems to deliver heating, dehumidification, or cooling. Over 31 studies have been performed on this problem over the last 16 years. These studies have covered all sections of the country, homes of all vintages, and homes of all common construction types. The overall view from these studies is that the average duct leakage exceeds 25% of the air flow through the system. The energy losses associated with this duct leakage are in the 15% to 20% range depending on the location of the leaks and system type (furnace, heat pump, or air conditioner).

At least eight of the more recent studies have included other determinants of overall system efficiency for air conditioners and heat pumps. These studies have shown incorrect refrigerant charge followed by low air flow come a close second to duct leakage in reducing the installed efficiency of the entire system.

These three problems contribute substantially to the installation of oversized air conditioners and heat pumps. Oversize units mask many system problems.

Despite the severity of the duct leakage problem, these studies have found that simple measures, such as sealing connections that should have been sealed at the time of installation, achieves an average 60% reduction in duct leakage. If simple measures are available then, "Why do the homes continue to be built with leaky ducts?" The answer is that changing construction practice is slow and meets with substantial resistance even if there is no cost penalty. When a duct connection is designed, actively marketed, and regularly applied that:

- will provide severely reduced duct leakage,
- will lower installation costs, and
- can be installed without significant changes in the installation method
- duct leakage efficiency losses can become a negligible problem.

Example Studies

Andrews et al. (1995), in an evaluation of new homes in Colorado, found that leakage from ducts in new construction averaged nearly half the flow in the system.
Proctor et al. (1997) measured the air flow and charge of air conditioning units as well as the leakage of the ducts and building shells in a sample of 28 systems. The investigation found that newly constructed homes in Phoenix have an average duct leakage of 193 CFM25.

Blasnik et al. (1995a), in a study of newly constructed residences in the Coachella Valley of Southern California, examined 10 houses with central air conditioners for installation practices and system performance. Even though the residences examined were newly constructed and all had received a utility financial incentive for installation of energy efficient air conditioners, significant deficiencies were found in all air conditioning systems. The predominate problem was duct leakage to the exterior. Testing indicated that the one-story houses had a much higher duct leakage rate than the two-story houses. The measured average duct leakage to the exterior was 441 CFM50 and 144 CFM50 respectively. The primary difference was found to be the extensive use of building cavity and platform return plenums on the single story houses.

The measured supply duct leakage, when corrected to the system operating pressures, represents an average of 9.5% of the air handler flow on the one story houses and 4.1% of the air handler flow on the two story houses. Return leakage was more than twice as large, averaging 20.8% and 11.6% in the two types of houses respectively.

Cummings et al. (1990), in a comprehensive study of 91 "typical" Florida houses, studied the effects of duct leakage HVAC system on energy use. Tracer gas testing found that infiltration rates for the houses were four times greater when the air handler was operating than when it was off. The average air changes per hour (ACH) for the 91 houses was 0.21 with the air handler off and it increased to 0.93 when the air handler was turned on.

Twenty-five houses received duct sealing work. Measured cooling energy usage showed on these homes showed an 18% reduction in cooling energy usage.

Hammerlund et al. (1992), in a study of newly constructed residences in the Los Angeles area, examined with installation practices and system performance for ducted heat pump systems installed in 66 apartments and 12 houses. The residences were newly constructed and most had received a utility financial incentive for energy efficient heat pumps.

The predominate problem in single family residences was duct leakage. The testing indicated that the vast majority of the homes had excessive duct leakage. This duct leakage resulted in an increased cooling load of approximately 30%.

The duct leakage to the exterior of the building was considerably lower on the multifamily residences. This was due to both shorter duct runs and lower operating pressures. However, low air flow through the indoor coil proved to be a more serious problem in the multifamily residences. Less than 15% of the units tested had the correct air flow through the indoor coil. Two thirds of the heat pumps in the multifamily residences were incorrectly charged.

3. TECHNICAL APPROACH

The development team considered duct connections for both new construction and for retrofit purposes. Changes in connector design can be most effectively integrated into new construction and into replacement retrofit. Repair retrofit can use many of the new design components along with existing technologies (mastic and mesh or aerosol sealing for example).

Task 1. Functional Analysis

Researchers applied a design approach developed primarily for cost reduction in major production industries. This approach first lists the functions served by the device/part/assembly. Once the functions of the device are fully defined and understood, designs are prepared to address these functions in the simplest, least cost, or otherwise optimized manner. In many cases this type of analysis can combine functions in a single device rather than a device for each function. John Proctor, P. E. of Proctor Engineering Group has used this methodology extensively to provide functional improvement and cost reductions in automotive design.

Analysis of duct connections showed two primary functions; sealing and fastening. Each prospective design was evaluated against these functions, their cost and reliability. By the end of the design process, these two functions were effectively joined into a single multi-function design.

Task 2. Option Expansion

For the next step of the investigation, researchers identified candidate duct connection systems for potential use. The considered methods previously tested or conceived by the development team and by Dr. Mark Modera of Lawrence Berkeley National Laboratory and new methods conceived by Proctor Engineering Group. Each of these options was reviewed for functional suitability and ranked for their cost (materials, manufacturing, transportation, labor) and commercial acceptability. A limited patent search was performed to find any other design concepts should be included (if there was a superior concept) or excluded (if there was a potential patent problem). The PEG team met and discussed the merits of each option over a four month period. An interactive meeting with LBNL team members discussed additional optional design concepts.

In all 126 design concepts were examined.

Methods that showed initial promise included shrink wrap and snap together fittings. The first group was externally applied fastening/sealing combinations that resemble "shrink wrap" that shrink to fit the joint and provide a permanent connection and air tight seal.

The shrinking can be activated by heat, chemicals, drying, or other means. The second group was lock/seal designs including: "twist lock," "pop bead," and tapered sleeve designs. These connection methods also combined with integral adhesive/sealant capsules, heat or chemical activated sealants, or other "passive" sealant technology (passive sealant is sealant applied without any intentional action of the duct installer).

Task 3. Design Selection

Using the functional analysis of Task 1, PEG evaluated, refined, redesigned, and culled the design concepts.

During this analysis the categories of new installation and retrofit were further defined into new installation, repair retrofit, and replacement retrofit. The category of new installation was sufficiently clear, but retrofit needed to be split into repair retrofit and replacement retrofit. Repair retrofit is defined as a duct repair where sealant and fastening is applied to existing duct systems. Replacement retrofit is defined as a duct repair where some new parts are used to achieve a permanent air tight connection. Replacement retrofit is applicable where repair retrofit would be too costly or impossible.

Repair retrofit at this point consists of mastic/mesh or the recently developed aerosol system invented by Dr. Modera. It was determined that the biggest advances in retrofit could be made in areas where the aerosol system was not applicable (very large leaks) and mastic/mesh methods were not meeting acceptance. The design addresses this market as well as the new installation market.

The design selected for proof of concept integrated the sealing and fastening function into a single part. This is a conical gasket on the male end of the connection that snaps into a locking grove in the female end. This design would provide a permanent locking, extremely low leakage connection suitable for new installations and repair replacements. The design was easy to install and made the installer's job easier by eliminating steps. Due to the reduction in installation time and installation cost, the overall cost of this design is expected to be equal to existing practice.

Task 4. Build, Test, and Refine Prototypes

PEG produced prototype design drawings, had the components fabricated, and assembled the prototypes. Two designs were constructed, a rigid sheet metal duct design and a helix core flexible duct design.

Proctor Engineering Group conducted leakage and fastening integrity testing on the prototypes. Leakage was tested using a fan to force air through the connection while measuring the air flow with a small orifice plate. All tests were run at 25 pascals pressure across the duct connection. Fastening integrity was tested by manually attempting to remove the female fitting from the male fitting through axial pulls, twisting, and bending.

The success of the seal and the fastening system is closely related to the following design parameters: clearance between the male and female fitting, thickness of the lock/gasket, conical angle of the lock/gasket, flexibility of the lock/gasket, retention of the lock/gasket in the male fitting, height of the lock/gasket, and others.

By varying the critical design parameters, the design was refined to achieve an excellent seal and a secure connection without the need for excessive assembly force.

The results of these tests are presented in more detail in Chapter 4.

Task 5. Patent Search

Three in depth patent searches were conducted.

For the first patent search, PEG staff searched the CLAIMS®/U.S. PATENTS database, produced by IFI/Plenum Data Corporation, which is accessed through Dialog Information Service. This database contains information from the United States Patent and Trademark Office (USPTO) on over 2.9 million United States patents, dating back to 1950. For the second search, PEG staff used the United States Patent and Trademark Office Patent Database. Both searches were performed via the Internet. The searches provided first page information on all patents. Any patent that bore resemblance to the design produced under this contract was ordered from the USPTO. Based on these reviews, PEG is convinced that the prototype design does not violate or infringe on any existing patents.

Once PEG's in-house search indicated that the design was patentable, a law firm, Goldstein and Associates was hired to conduct a "manual" patent search in the United States Patent Office in Washington D.C. of all patents issued in this country since 1790. The patent attorneys provided a professional opinion that the design differed from the other patents and that the design is patentable without infringement on other patents.

Task 6. Revision and Re-Test

Proctor Engineering Group revised the designs based on the results of Task 4. The revised designs also incorporated changes for ease of manufacture. These designs were given to LBNL to build and test. These prototypes showed similar performance to the initial prototypes built and tested by PEG. The results of the LBNL tests are summarized in Chapter 5.

Task 7. Data Analysis and Conclusions

The team reviewed test results showing leakage reduction and attachment integrity and determined that the prototype met the design goals of ease of use, permanence, and air tight seal.

Task 8. Outline Future Work Plan

The team members outlined the steps to commercialization, summarized the key issues needing further research, and developed a plan for commercialization. This plan includes:

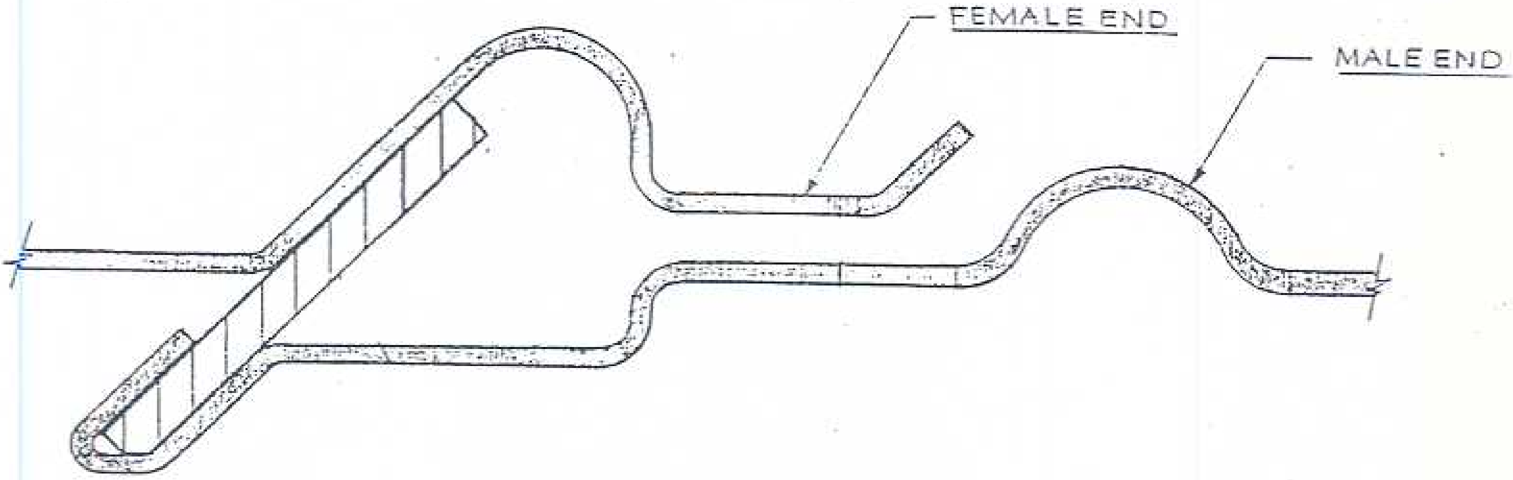
- Finalize gasket material selection.
- Establish a working relationship with a major duct component manufacturer. Once all tooling needed for production is in place initial runs will be produced and the production materials will be tested.
- Apply for a patent for the connection design and components.
- Contract with the duct component manufacturer for the production of quantities of duct components sufficient for field testing in subdivisions.
- Train installation contractors and oversee the installation of the field test sites. Performance testing will be provided to confirm the system leakage rates, airflow characteristics, and static pressures. Data will be gathered from the installation contractors concerning the installation process and improvements.
- Collect feedback on potential improvements uncovered in the installation process.
- Complete the cost/performance trade-off analysis.
- Test marketing plan in two areas.

4. THE PROFESSIONALLY ENGINEERED DUCT SYSTEM DESIGN

The Professionally Engineered Duct System can be applied to all types of duct systems, including round, oval, and rectangular rigid sheet metal ducts, as well as helix core flex ducts. It has a snap-together fitting that uses an embedded semi-rigid flexible gasket. The conical gasket on the male end of the connection that snaps into a locking grove in the female end. When snapped together, the connection forms a nearly air-tight connection that cannot be separated without exceptional force.

Figure 4-1 details the fitting in an assembled state.

Figure 4-1



PEG constructed two connection prototypes, a rigid sheet metal duct and a helix core flex duct, and conducted laboratory tests to determine each one's leakage. The first design tested was a 6 inch diameter round sheet metal duct constructed with 26 gauge material. This is the same material used in current residential systems. The second was a helix core flex duct fitting over a 6 inch diameter sleeve.

The success of the seal and the fastening system is closely related to the following design parameters: clearance between the male and female fitting, thickness of the lock/gasket, conical angle of the lock/gasket, flexibility of the lock/gasket, retention of the lock/gasket in the male fitting, height of the lock/gasket, and others.

PEG tested various clearances and angles, as well as gasket materials. Gasket material tests included different metal gaskets, different gauges, and various elastomeric materials and thicknesses. The majority of the combinations provided some combination of too difficult assembly force, inadequate attachment security or too much leakage. The gasket material tested that provided the best sealing and assembly characteristics, along with the ability to provide a secure fastening closure, was 1/16" fabric reinforced rubber. Results of air leakage tests for the 1/16" fabric-reinforced rubber gasket were impressive.

Sheet Metal Duct Air Leakage Tests

Table 4-1 presents the results of the air leakage tests for the prototype against air leakage for standard rigid sheet metal ducts. Air leakage is presented as a measure of cubic feet per minute (CFM) with the duct connection pressurized to 25 Pascals (a standard ASHRAE residential duct leakage test pressure).

The first connection type in Table 4-1, a round duct crimp connection installed to reveal one-half inch of the crimped section, is typical of current installations. In this configuration, the duct is slipped together without regard for how tightly it pushes against the stop provided. The standard connection was not sealed since the typical joint is either unsealed or sealed with duct tape that fails in short order. This connection type had a leakage of 2.20 CFM at 25 pascals.

The second connection in Table 4-1 is the leakage of the same fitting when it is installed with the female end of the fitting bottomed against the stop in the male end. Again for this test no sealant was applied.

The third connection in Table 4-1 is the prototype fitting. The prototype fitting was inserted until the interlocking action was completed. Prototype fitting leakage was equivalent to 1/20th of the typical connection.

Table 4-1. Rigid Sheet Metal Duct Leakage

Connection Type	**CFM**
Standard crimp connection round duct installed to a 1/2 inch reveal of the crimped portion of the fitting	2.20
Standard crimp connection round duct installed to seat firmly against raised stop	0.26
Prototype gasket connection	0.11

No effort was made to front seat or back seat the gasket in the connection of the prototype fitting (front seating is pushing the gasket in as tight as possible in the female fitting) because installers will not conscientiously apply the connection in a front seated manner . All leakage characteristics are reported with the connection inserted until the gasket snaps in place. PEG also tested leakage with the gasket front seated. This test showed a leakage of 0.06 CFM (2.8% of the standard fitting).

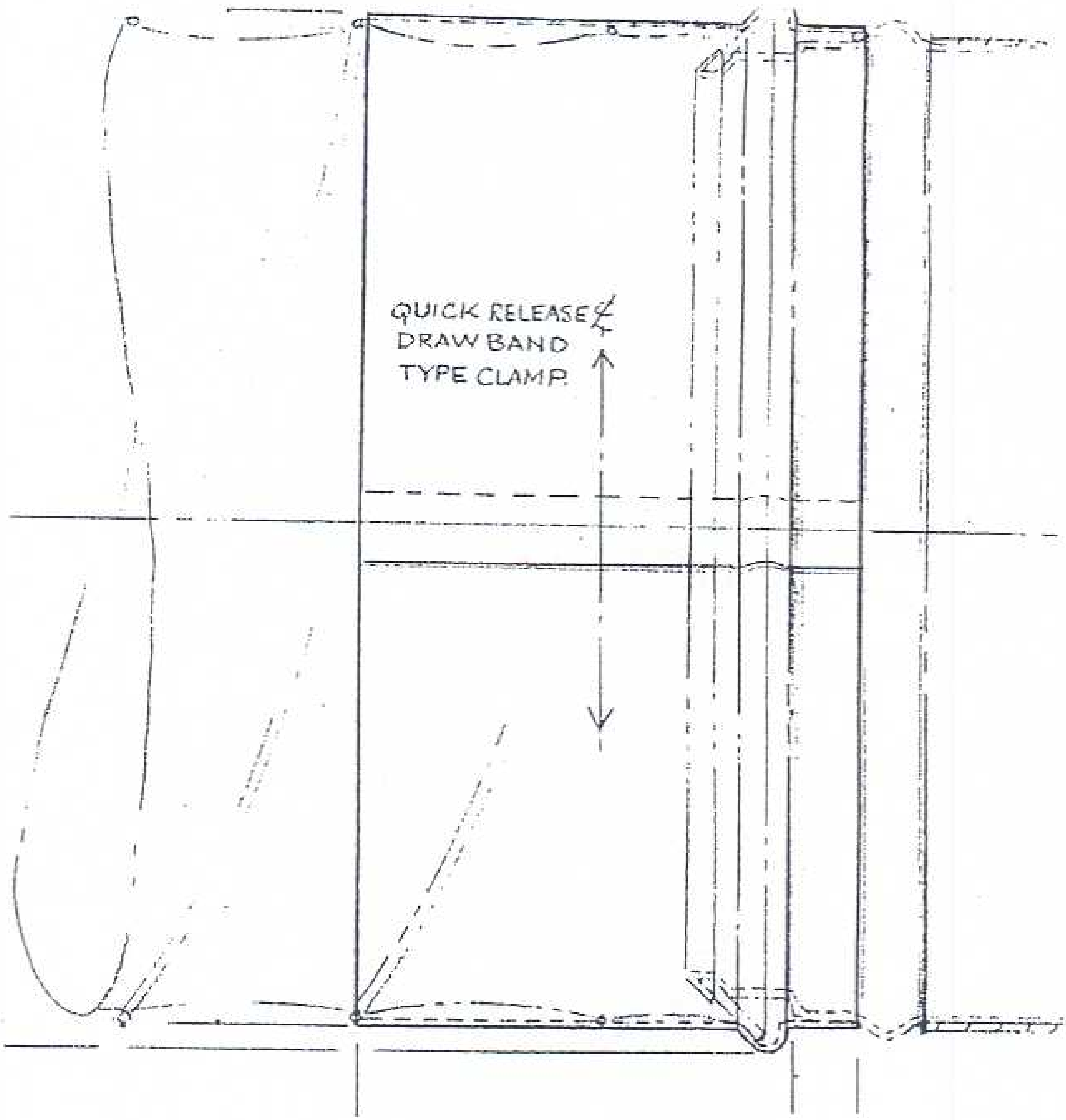
The connection was examined to determine the holding strength when subjected to axial pulls, twisting, and bending. The connection held firm when subjected to force equivalent to someone leaning on, pushing, or kicking the connection. The most extreme force applied did increase the leakage to 0.39 CFM (18% of the standard connection leakage).

Helix Core Flexible Duct Leakage Tests

The flex duct design incorporates the same gasket/lock and locking grove system. In the flex duct design the flex duct inner liner is compressed between the male fitting (with the gasket) and the outer ring which has the locking grove.

Figure 4-2 details the flex duct fitting in an assembled state.

Figure 4-2



The results of the testing on the flex duct connection prototype are presented in Table 4-2.

Table 4-2. Helix Core Flex Duct Leakage

Connection Type	CFM
Helix core flex duct installed on a crimp connection installed to a 1/2 inch reveal	0.72
Prototype gasket connection	0.07

As shown in Table 4-2, the leakage at a typical flex duct connection is 0.72 CFM, 33% of a typical metal-to-metal crimped connection. This fact should not cause the reader to conclude that typical flex ducts are better than metal ducts. A flex duct is easily removed by an axial force which slides the inner liner off the male connector. This is true even with properly tensioned cable ties. In addition, flex ducts are very prone to bending and crimping that severely reduce air flow.

The prototype duct connection has 1/10th the leakage of a standard connection, and it provides a positive means of securing the connection.

Meeting Uniform Mechanical Code Requirements

The team investigated the ability of the design to pass the Uniform Mechanical Code (UMC) established by The International Association of Plumbing and Mechanical Officials. The UMC is the most commonly referenced and adopted code in jurisdictions across the U.S.

The Professionally Engineered Duct System design concept meets all codes applicable to sealing and fastening methods. For sealing duct joints and seams, the UMC states that duct joints and seams shall be made substantially air tight by means of tapes, mastics, gasketing or other means. The prototype design meets this standard by using a gasket to seal the duct joint substantially tighter than the standard connection. For mechanical fastening, the UMC addresses very specific types of ducts. The closest design covered by the UMC is the standard sheet metal crimp connection. The UMC states that crimp connection joints shall be mechanically fastened by means of at least three sheet-metal screws equally spaced around the joint, or an equivalent fastening method. The prototype design demonstrates fastening equivalent to sheet-metal screws.

6. CONCLUSIONS AND RECOMMENDATIONS

The Professional Engineered Duct System developed in Phase I is feasible for the existing manufacturing process with small tooling changes (new rollers). All components are constructed of materials of the same gauge and diameters used in current production. The snap-together design is less installation labor-intensive than current technology, it can be easily integrated into the current production processes, allows only a very small fraction of leakage compared to existing technologies, and resists accidental or intentional disconnection.

The Professionally Engineered Duct System design concept meets applicable codes established by the International Association of Plumbing and Mechanical Officials. The design produces leakage rates between 5% and 30% of existing designs. It does not infringe on any existing patents and is patentable.

Benefits to be gained by industry application of the Professionally Engineered Duct System include the following:

Operating and Performance Improvements

Minimal air leakage. Today's typical installations have efficiency losses due to air leakage in the 30% range. The PEDS nearly eliminates between 70% and 95% of the joint leakage.

Reduced heating and cooling loads. With airtight ducts, the heating and cooling loads are lower. The industry can use smaller equipment to provide comfort to the customer at lower initial cost.

Decreased energy use. By delivering the conditioned air to the space for which it was intended, the run time of the air conditioner, heat pump, or furnace is reduced. This reduction can be significant. Reviewed studies found AC savings in the 12% to 20% range for leakage reductions of 60%.

Decreased peak energy usage. The negative effects of leaky, partially disconnected, and disconnected ducts worsen with extreme temperatures. This is primarily because all duct leaks result in increased infiltration. This infiltration at extreme (peak) temperatures drives the peak demand much higher. PEDS not only lowers peak watt draw but also lowers transmission and distribution capacity needs.

Improved indoor air quality. The furnace, heat pump, or air conditioner fan is the largest capacity fan in most homes. This fan is almost always connected to a leaky duct system. When supply ducts leak more than return ducts, this powerful fan depressurizes the home with serious indoor air quality effects. Negative pressure, caused by duct leaks, increases the potential for water heater, furnace, and fireplace malfunction, backdrafting, intrusion of soil gases, moisture, and other undesirable situations.

Social Benefits

PEDS offers environmental and economic benefits to society. Reducing duct leakage offers significant potential to reduce greenhouse gases. Individual gas furnaces will show reduced consumption and emissions. Utility power plant generation and emissions will be reduced in winter for electrically heated homes and in summer for air-conditioned homes.

The chief economic impact of PEDS will be customer cost savings achieved through the reduced lifetime energy expenditures. Commercial Impact

The Professionally Engineered Duct System can be readily incorporated into existing HVAC businesses, offering commercial opportunities to home builders, manufacturers, equipment dealers, contractors. The system can be manufactured by existing duct/sheet metal production firms and distributed by the conventional, local distribution network. It does not require any major deviation from standard transportation and warehousing activities. It can be installed by the local contractor network and by existing personnel. Its relatively easy commercialization potential offers a real opportunity to substantively reduce residential HVAC energy consumption and associated environmental impacts, while providing noticeable improvements in customer health and comfort.

Ease of Adoption

The PEDS meets both air sealing and mechanical fastener requirements. The snap-together system is faster, simpler, and more foolproof to install than any existing system and its components adapt to a wide variety of systems. The availability of PEDS will motivate the industry to create air-tight ducts as a byproduct of cost and convenience considerations.

Industry Interest

An interest in quality duct installations exists. Builders, HVAC contractors, utilities, and other parties have to be involved in early demonstrations of the technology. The predominant builder in Chicago (Town and Country Homes) has agreed to provide a demonstration site during Phase II of the project.

Recommendations

Based on the performance characteristics and anticipated benefits, the research team recommends:

- finalizing the component designs for both rigid sheet metal and helix core flex duct

  The finalized designs would take into account the results of the ongoing LBNL tests and manufacturers' input.

- a test run of components be produced on production machinery
- a final material selection based on;

  the ability to maintain shape and physical properties in an environment from 30°F to 250°F

  the flexibility to allow the duct components to be connected without excessive resistance

  the rigidity to provide a stable brace against forces applied to dislodge the connection

  applicable certification tests for use in a residential air distribution system.

- that HVAC contractors be trained and duct systems will be installed in two housing subdivisions, one in the Midwest and one in the western United States.
- cost analyses be continued and any needed design changes made prior to commercialization.

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