Innovations Deserving Exploratory Analysis Programs

Highway IDEA Program

Advanced Cleaning Device to Remove Debris and Chemicals for Crack/Joint Sealing in Pavement

Final Report for
Highway IDEA Project 159

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IDEA Program Final Report

NCHRP-IDEA 159

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The National Academies

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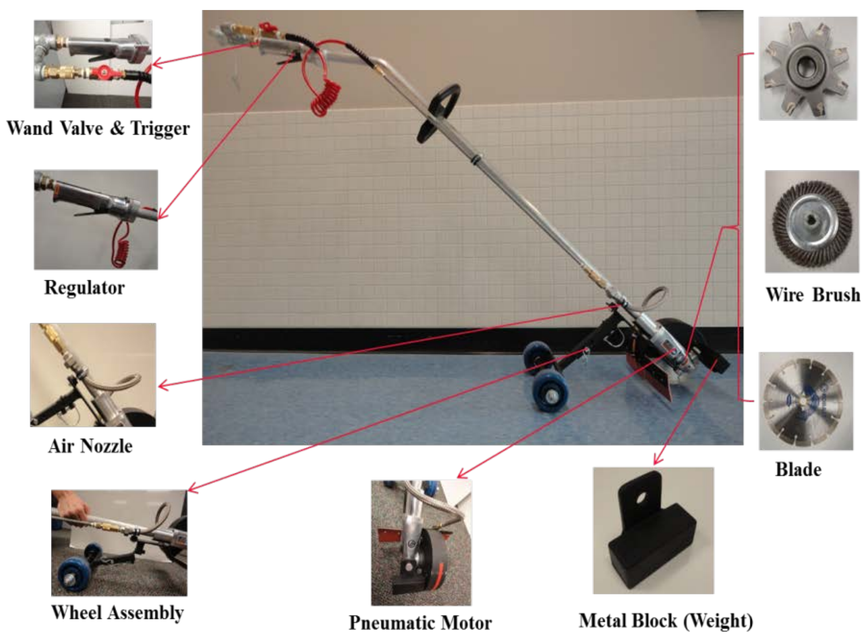
EXECUTIVE SUMMARY

The aims of this project were to improve and retrofit the design of a pavement crack cleaning device (CCD) developed in the previous IDEA Type I project (NCHRP-148), to make it more practical and functional by adding functions such as routing, hot air blasting and vacuuming. As an outcome of the previous research, a conceptual prototype of a crack cleaning device was innovatively designed, utilizing pneumatic power for air blasting and abrasive wire brushing to simultaneously remove debris or de-icing chemicals which were used in cold winter and remained in cracks. In the current project, a router, an electric heat lance and a vacuum system have been incorporated as possible options for the CCD. An electrical heat lance has been designed to properly warm the pavement and expel moisture to promote bond adhesion. In addition, a vacuum system has been developed as a means of collecting debris and dust to remove road hazards and improve operator safety while conforming to OSHA and EPA guidelines. Routing and saw cutting functions have been added to the CCD as well. Fig. 1 shows the versatile functions of the CCD.



(b) Heat blasting function

(a) Routing, brushing, cutting, air blasting functions

(c) Vacuum function

Fig. 1. Versatile functions of CCD

For validation of the CCD in the field and to gain industry acceptance of the CCD technology, several industry demonstrations and field tests have been conducted (Fig. 2). Multiple CCD units have been provided to the Nebraska Department of Roads (NDOR) for use during the full sealing season in 2012-2013, which was financially supported by NDOR. Also, demonstrations have been conducted at the Crafco Inc. manufacturing facility in Chandler, AZ and at the City of Omaha, NE, road maintenance division. Productivity data along with the crews' feedback were collected during the field tests. The analyzed results showed that the CCD design concepts have been well received by all participating industries, who expect the CCD will positively impact highway road maintenance by improving productivity, safety and maintenance cost. Crafco Inc. has shown strong interest in commercialization of the CCD, and commercialization efforts currently are underway between the PI's institution and Crafco Inc.

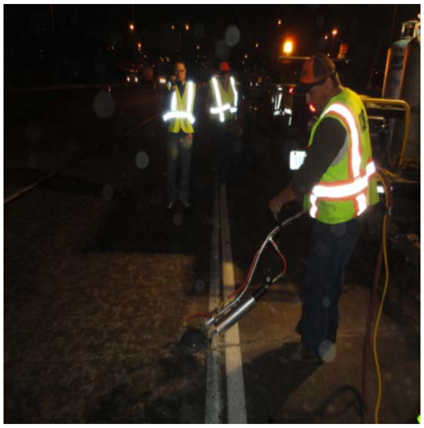


Fig. 2. CCD heat lancing test by a NDOR crew

If successful in commercialization and industry adoption, utilizing the CCD for crack and joint preparation would lead to an increase in overall quality of pavement maintenance, increase the useful life of pavements, and reduce costs toward rehabilitation or new construction of roadways.

1. INTRODUCTION

Cracks in flexible and rigid pavement occur when stress builds up in surface layers due to water or debris infiltration. Various crack sealing and filling methods can be used to repair pavement surfaces, depending on crack sizes and crack types. In “Materials and procedures for sealing and filling cracks in asphalt surfaced pavement” (FHWA-RD-99-147), the Federal Highway Administration recommends crack sealing for small cracks measuring 5 to 19 mm (Smith et al. 1999). Also, Unified Facilities Criteria (UFC) provides guidelines for crack preparation based on crack size as shown in Table 1 (Basham 2001).

Table 1.1. Crack Preparation Methods Based on Crack Size

Crack size	Hairline cracks: less than 1/4 inch (<6 mm)	Small cracks: 1/4 to 3/4 inch (6 to 19 mm)	Medium cracks: 3/4 to 2 inches (19 to 50 mm)	Large cracks: greater than 2 inches (>50 mm)
Crack cleaning method	No preparation required	Routing to widen the cracks to a nominal width of 1/8 inch (3mm) greater than existing nominal or average width	Sandblast, heat lance or wire brushes, followed by compressed air	Cut and filled, prepared in the same manner as potholes

The traditional procedures for preparing roadway cracks for sealing/filling are largely ineffective, labor intensive, or dusty. Further, working crews can be often exposed to safety hazards. A brief summary of merits and drawbacks of each method is described in Table 1.2. Although routing is the best approach among the methods listed below for cleaning cracks, it is not a solution for complete crack preparation. Routing only excavates narrow cracks and still leaves de-icing chemicals on both sides of the crack surface. However, surface preparation is very important for better bonding between surface and sealing material, and thorough cleaning is essential. In addition, the heavy router machine currently used by most of state Department of Transportation (DOT) agencies for routing cracks has several obvious shortcomings, such as heavy weight, unsafe operation, slow mobility and high equipment and operation/maintenance cost.

Table 1.2. Summary of Conventional Methods of Crack and Joint Preparation

	Merits	Drawbacks
Air Blasting	Effectively expels dust and relatively loose contaminants; convenient and fast	Difficult to clean out vegetation, de-icing chemicals, large debris
Heat Lance	Removes moisture, especially in cold weather	Sealant bond failure caused by overheating; overheating introduces more moisture from frozen ground; high propane price; safety issues (direct flame)
Sandblasting	Efficiently removes de-icing chemicals	Over-blasting can damage the pavement; environmental and health concerns
Routing	Opens small cracks or joints and cleans out debris; effective on straight cracks	Not effective for random narrow or wide cracks (not easy to follow random crack lines); heavy machinery may create new cracks; pulling mechanism is very dangerous in downhill
Wire Brushes	Effectively remove de-icing chemicals and vegetation on medium cracks	Not easy to remove residual debris from narrow and small cracks

In cold weather regions, hot air blasting is a popular crack cleaning method. Hot air blasting typically uses a compressed air heat lance that introduces gas and combustion to the compressed air to provide a jet of hot air to the treated area. However, hot air blasting introduces problems as well. Extreme caution must be taken to ensure the pavement is not overheated, which will result in the asphalt binder becoming brittle and leading to premature failure and may introduce more moisture from the frozen ground. Care also should be taken to never allow use of direct flame methods, as the charring effect will lead to soot residues and cause poor initial bonding. Such direct flame problems occur frequently with current practices (Fig. 1.1). In addition, hot air blasting does not clean de-icing chemicals that remain in and around the cracks. Furthermore, propane regulators often freeze in cold weather, thus delaying the sealing process.

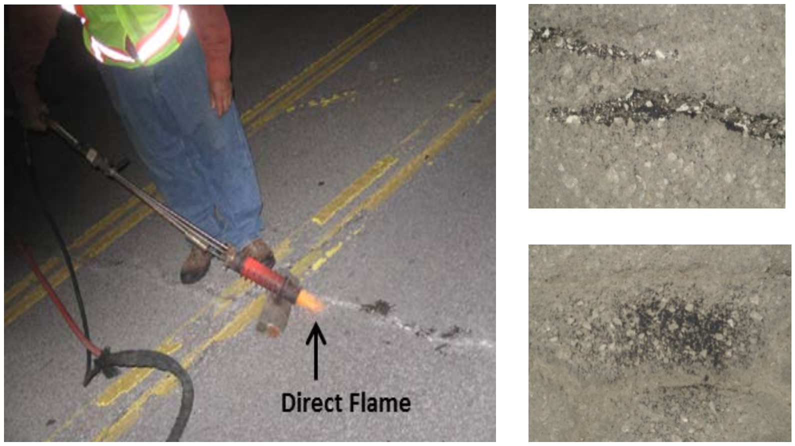


Fig 1.1. Direct flame problem in hot air blasting (heat lance) causing soot residues

Development of the multi-function crack cleaning device was initiated by a practical request from the Nebraska Department of Roads (NDOR) for a tool that efficiently prepares pavement cracks and joints for sealing. NDOR was particularly interested in the tool's ability to remove de-icing chemical buildup that forms in cracks and prevents sealant adhesion. From the previous IDEA Type I project (NCHRP-148), a customized versatile Crack Cleaner Device (CCD) was developed with two main integrated cleaning methods: compressed air blowing and wire brushing. The device utilizes a pneumatically powered rotary wire brush to clean stubborn vegetation and accumulated de-icing materials from mid- to large-size pavement cracks. Directly behind the rotary brush, an air blasting nozzle further expels fine-grained particles. The purchase price for the tool itself is low, and it effectively and efficiently prepares pavement cracks and joints for sealer or filler, which will further reduce long-term pavement maintenance cost.

While presenting or demonstrating the CCD to state DOTs and manufacturing companies during the Type I research period, routing, heat lancing and vacuuming functions were identified as other industry-driven needs for crack/joint preparation. Adding these options became a major focus of advanced device development. Heat lancing is used when pavement cracking typically occurs in moist and/or cold climates. If pavement temperature is lower than 40F, the pavement surface may be warmed with a heat lance that puts no direct flame on the pavement (Crafco 2008) while removing any additional moisture in the crack, both of which are critical to obtaining proper material adhesion. In this research, performance tests were conducted to evaluate the effectiveness of the developed heat lance system under different parameters of pre-heating time, air pressure, heating temperature, moving speed, etc.

Crafco Inc. also had indicated that a vacuum component is needed to meet a number of the state's environmental protocols to make it safer for the pavement crew and traffic. To design the vacuum system, a required velocity of air (CFM: cubic foot per minute) was measured and tested with dust and various sizes of debris on the pavement. Technical development was needed to design an appropriate configuration that would fit behind the brushes/router bit, while providing enough power to capture large-sized debris and not just fine particulate created from the brushing and routing processes.

2. CONCEPT AND FUNCTIONS

2.1 Heat Lance Development

2.1.1 First Generation

In the initial stage of the heat lance development, a piece of nichrome wire was used as a heating element, installed in a ½" copper pipe lined with high-temperature fiberglass to insulate the wire from the copper pipe (Fig. 2.1). The average power was 1520W at 80VAC, and the mass required approximately 10 seconds to reach operating temperature. The exterior case temperature was higher at the exit side, matching the highest air temperatures and decreasing to room temperature toward the inlet. At low pressure the heating elements glowed at a steady light red but quickly dimmed as pressure increased.

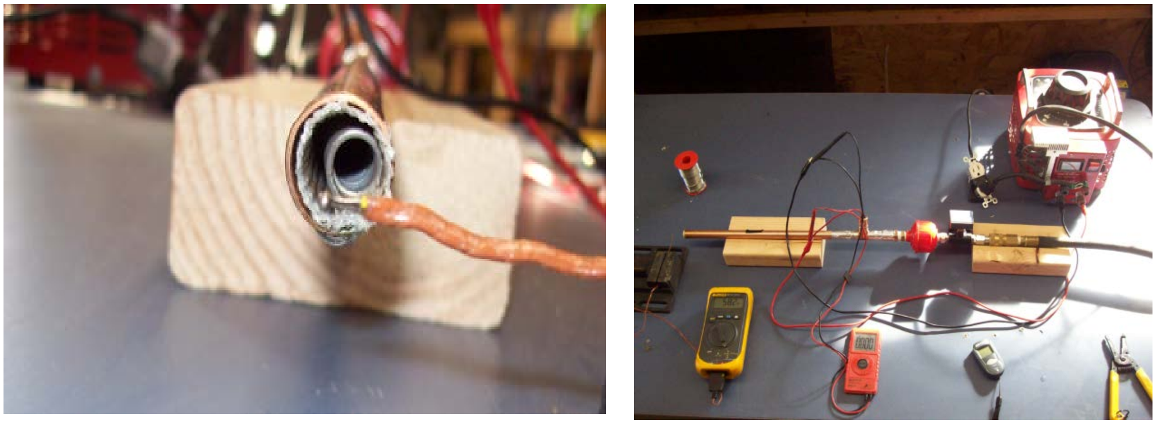


Fig. 2.1. A simple heat blasting test set for a single heat element

2.1.2 Second Generation

A multi-element heating unit was developed to increase air temperature at the outlet of the pipe. This model measured 2” in diameter and was 17” long (Fig. 2.2). Four heating elements in ceramic tubes were used to generate an average power of 2000W at 110VAC. Similar to the first prototype, the exterior case temperature was higher at the exit side, matching the highest air temperatures and decreasing to room temperature toward the inlet side.

Fig. 2.2. Second generation of heat blasting unit

2.1.3 Third Generation

The new heat lance with larger heating capacity was manufactured to operate on 240VAC single phase and has an operating power of 1150W (Fig. 2.3). The heat lance body measures 3” in diameter and 25.5” in length. The range of operating pressure is between 1 psi and 20 psi. The designed maximum tolerance of inlet temperature is 250°F, and the maximum tolerance of outlet temperature is 1000°F. Air enters the heat lance through the cold air inlet and flows through two chambers to increase the amount of time it remains inside the heat lance. The air is forced past the heater coils inside a cluster of six ceramic tubes (Fig. 2.4), which are sealed off at the top with high temperature silicone (700°F max) to prevent air leakage between the chambers. The heated air moves back to the inlet side of the heat lance past the outside of the ceramic tubes and travels to the outlet tube, then takes one more pass thorough the inside before exiting the outlet.

For protection from overheating due to either low pressure or high inlet case temperature, the unit has a built-in pressure and temperature monitoring circuit. The unit turns on power to the heater element only if the inlet pressure is above ambient pressure and the inlet case temperature is below 250°F. To ensure safety during operation, a LED indicator on the top indicates the state of the heat lance.

Fig. 2.3. Comparison of second and third generation heat lances

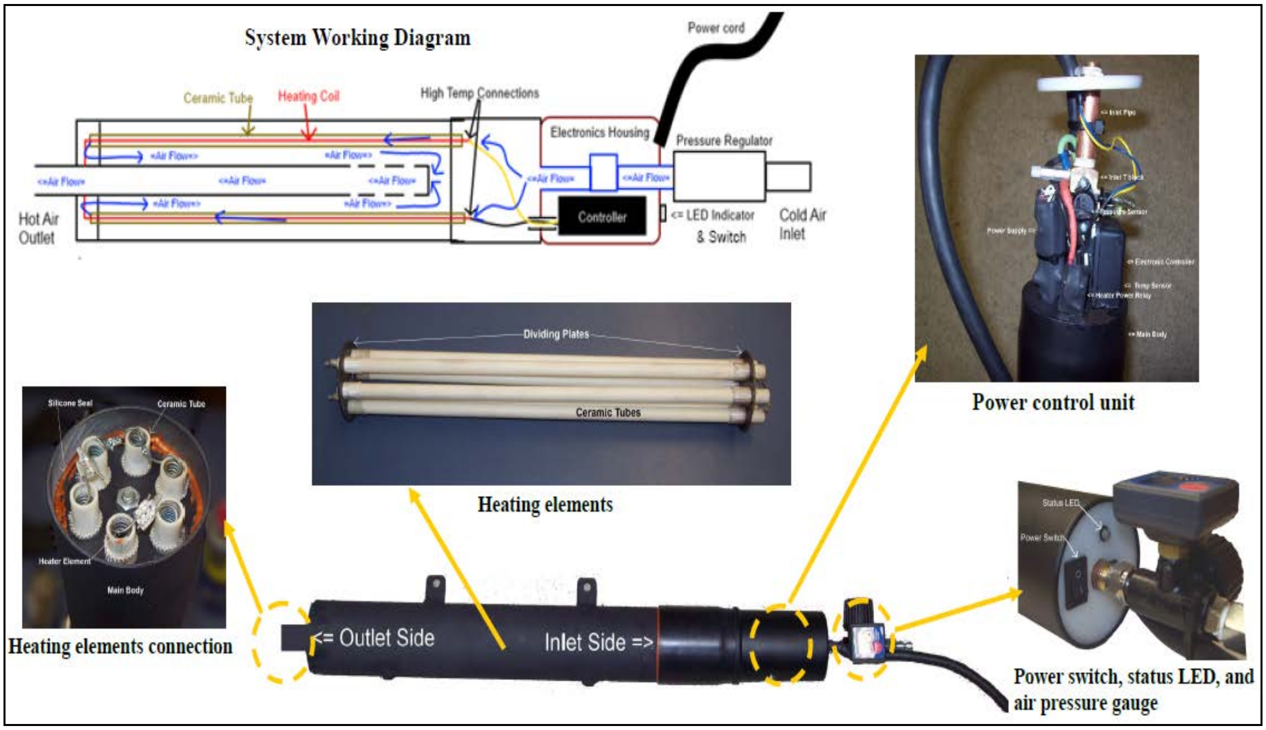


Fig.2.4. Third generation of heat lance unit

2.2 Vacuum Development

2.2.1. Vacuum Prototype

A vacuum unit, designed to be attached to the CCD, removes debris and dust from the pavement surface while cleaning the cracks. In the initial design, the vacuum unit was positioned directly behind the guard and vertically 1 inch off the ground (Fig. 2.5). While dust could be collected, some of the debris was deflected away from the guard and could not be sucked up by the vacuum. In addition, larger particles like gravel were difficult to collect with limited suction power.

Fig. 2.5. Original vacuum design

2.2.2 Updated Vacuum Design

After multiple trials, the vacuum design was changed, particularly for the direction of the collector opening. The suction opening is now positioned directly behind the rotary attachment (e.g., brush, blade, or router) at an angle that enables the running attachment to kick debris and particles into the opening of the suction hose (Figs. 2.6 and 2.7). With this change, relatively larger particles can be collected as well. Further, the wider iron guard around the hose opening collects more dust and particles, and a brush row that was added to the bottom and interior guard sweeps the floor and stops debris from being deflected away through a crack groove (Fig. 2.6). In our lab tests, particles such as old sealant and cement debris were effectively collected.

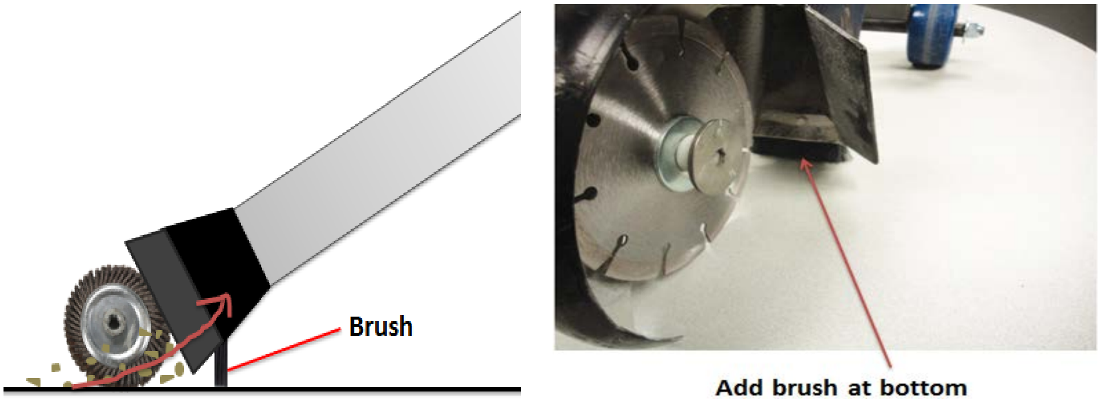


Fig. 2.6. New design concept using kicking mechanism

Fig. 2.7. Updated vacuum design with the kicking mechanism

2.3 Router Mechanism

A router is used mainly to create a sealant reservoir by enlarging meandering cracks to the desired depth and width. The simple and innovative design of the CCD has a pneumatically powered rotary motor to drive the router bit for excavation. The interchangeable attachment design allows for replacement of the router bit with a wire brush or a masonry blade. A metal block attached to the top of the motor provides weight to push the rotary motor down to alleviate user fatigue and to stabilize the CCD from bouncing torque. The weight of the metal block for routing is 10 lbs., which is 4 times heavier than the smaller block used for brushing and cutting (Fig. 2.8).

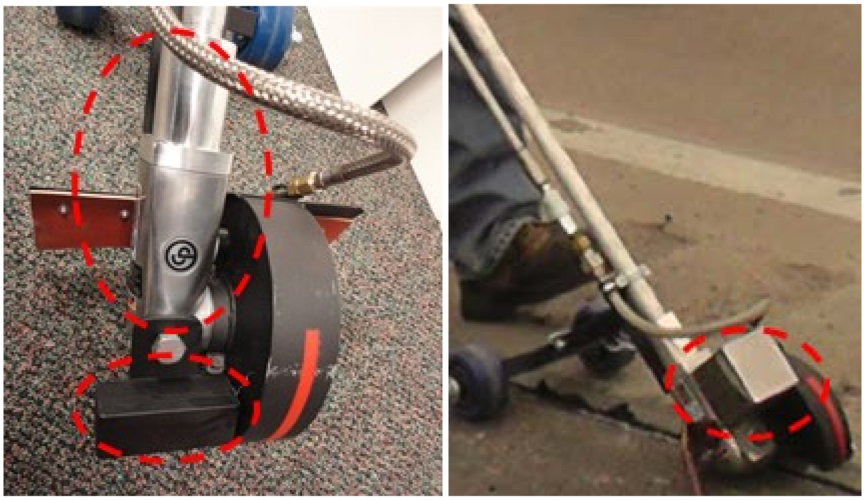


Fig. 2.8. Pneumatically powered rotary motor & metal blocks

2.4 System Configuration

2.4.1 Ergonomic Shaft Design

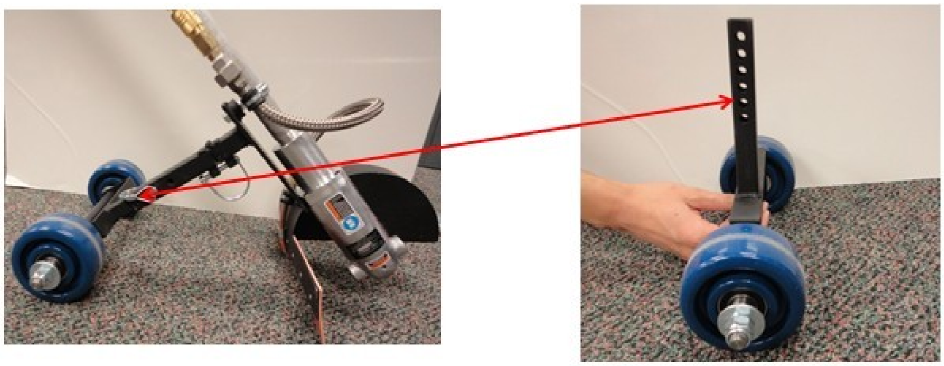
The shaft required a modified design after the first heat lance was installed. The shaft was changed from s-shape to straight to allow for a more functional design. With this configuration, the heat lance is better aligned with the shaft and less susceptible to damage since it is fitted next to the shaft (Fig. 2.9).

Before After

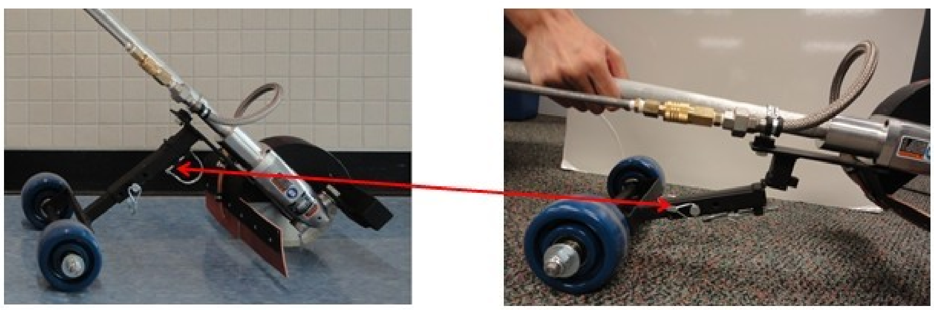
Fig. 2.9. Comparison of shaft configurations

2.4.2 Wheel Assembly Design

The design of the wheel assembly was changed from one wheel on the front right corner to two wheels behind the motor to absorb torque, thus reducing torque-induced fatigue in the CCD operator. This wheel configuration also allows the CCD to be free standing since the wheels are behind the center of gravity. The wheel assembly also is foldable for easier transportation and can be adjusted to raise or lower the height of the handle (Fig. 2.10).



(a) Adjust height of wheel assembly



(b) Foldable wheel assembly

Fig. 2.10. Rear wheel assembly design

2.4.3 Air Wand Design

Although plenty of air comes out of a nozzle behind the rotary attachment to clean loose particles from cracks, a larger volume of air is still needed to clean away dirt, debris and/or vegetation on the pavement surface resulting from the routing or brushing process. Traditionally, a leaf blower or an air wand directly connected to an air compressor is used to clean the pavement surface after cracks are routed. To eliminate this additional task, we developed a detachable air wand (3/8" inner diameter) that is easily connected to the CCD (Fig.2.11). After routing or wire brushing, the air wand can be used to clean cracks and the pavement surface, eliminating the process of disconnecting the CCD from the air compressor to use a traditional air wand to clean the pavement (Fig. 2.12).

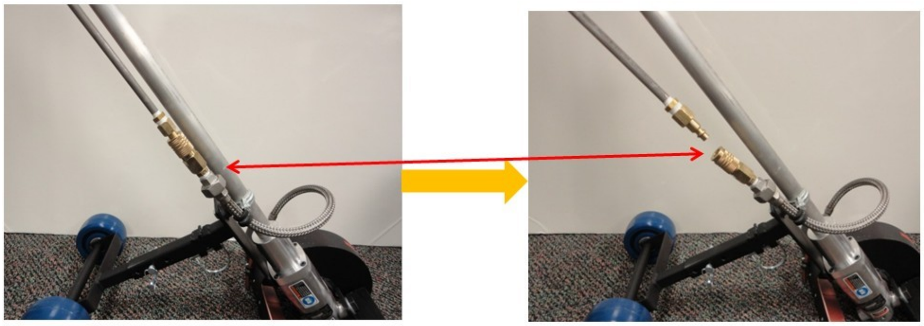


Fig. 2.11. Easy connection of air wand

Fig. 2.12. Using a detachable air wand for pavement surface cleaning by an NDOR crew

2.4.4 Protection Guard Design

A larger guard was placed on the back to offer the operator more protection from flying debris. The larger guard also provides a spot for mounting an air blasting nozzle or a heat lance nozzle (Fig. 2.13).

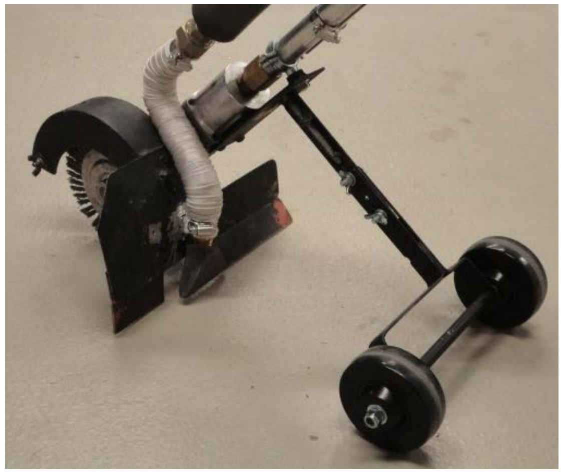


Fig. 2.13. Protection guard design

3. PERFORMANCE TESTS

The performance of the device was measured through lab and field tests. The main purpose of the lab tests was to test and improve the design of mechanism, and measure the effectiveness of proof of concept design through quantitative data or observation (e.g., temperature, cleaning speed, debris and dust collection, etc.). The main purpose of the field tests was to demonstrate the device to the field road maintenance crews at their working sites to get their practical feedback for design improvement and measure the performance comparison data between their current methods and the proposed device.

3.1 Lab Tests

3.1.1 Heat Lance Tests

The updated heat lance (third generation) with larger heating capacity was designed so a nozzle could be directly connected without a hose. The heat lance was tested outside to evaluate the relationship among air pressure, heated air temperature and moving speed. Quantitative data were collected by measuring the drying speed from the wet pavement surface in 15°C (59°F) outside air temperature (Fig. 3.1).


Fig. 3.1. Speed test for the third generation heat lance

As shown in Fig. 3.2, it took about 10 minutes for the heat lance to reach a temperature of 252°C (486°F). The exit air temperature decreased as the air pressure increased (Fig. 3.3). Due to the limited capacity of the air compressor in the lab, we tested only up to 20 psi of air pressure. The moving speed of the heat lance was positively proportional to the inlet air pressure, indicating that drying speed is faster when air pressure is higher (Fig. 3.4). Due to the relatively lower exit air temperature compared to the heat lance with propane gas, no signs of overheated spots appeared on the tested pavement surface.

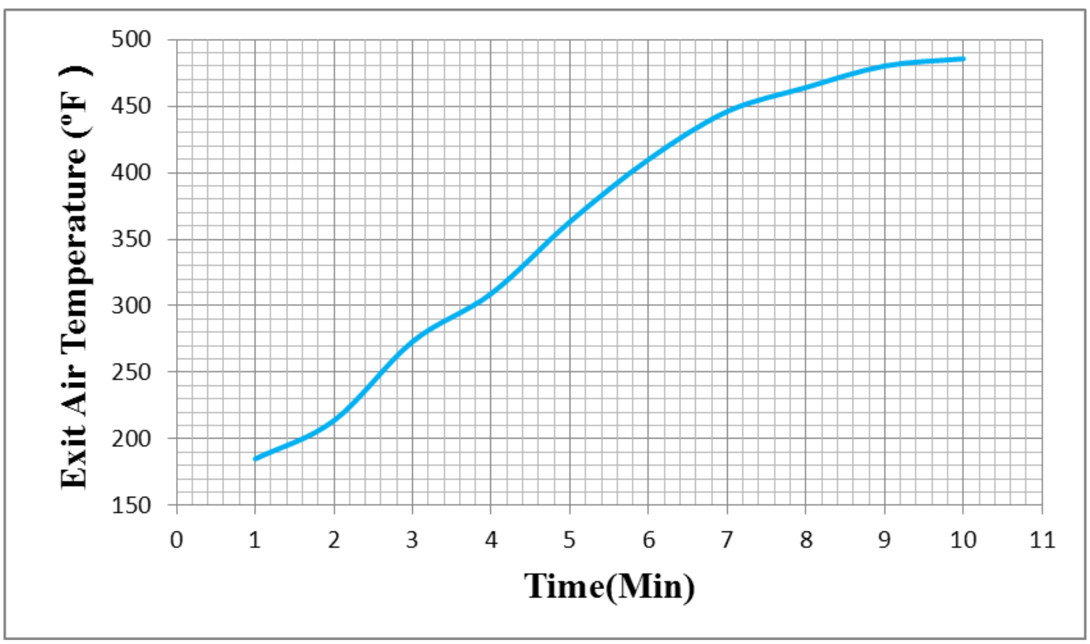


Fig. 3.2. Lab test of heating process

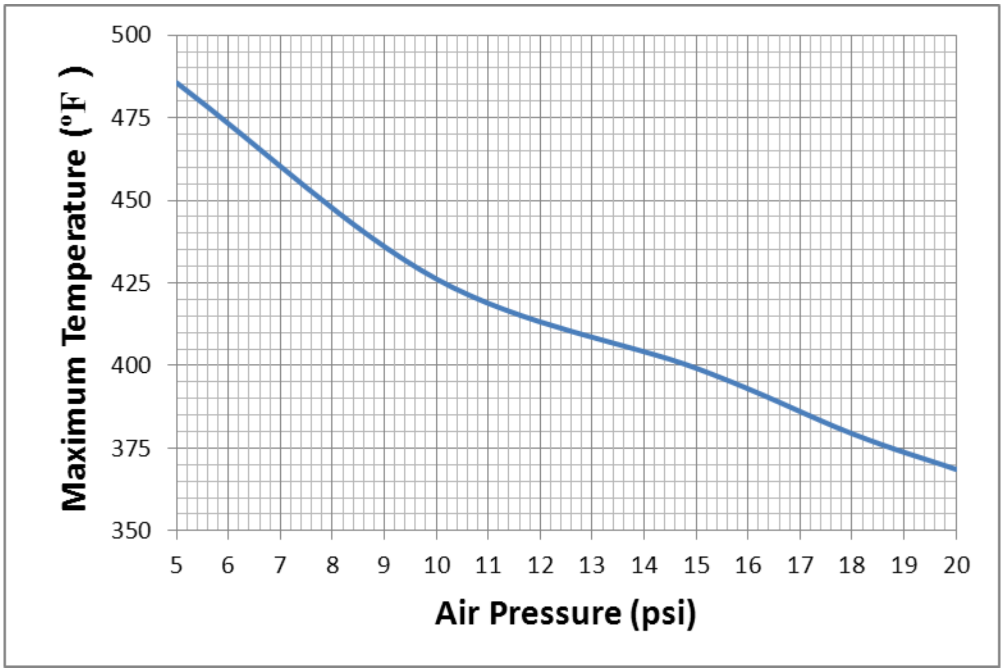


Fig. 3.3. Lab test of relationship between maximum temperature and air pressure

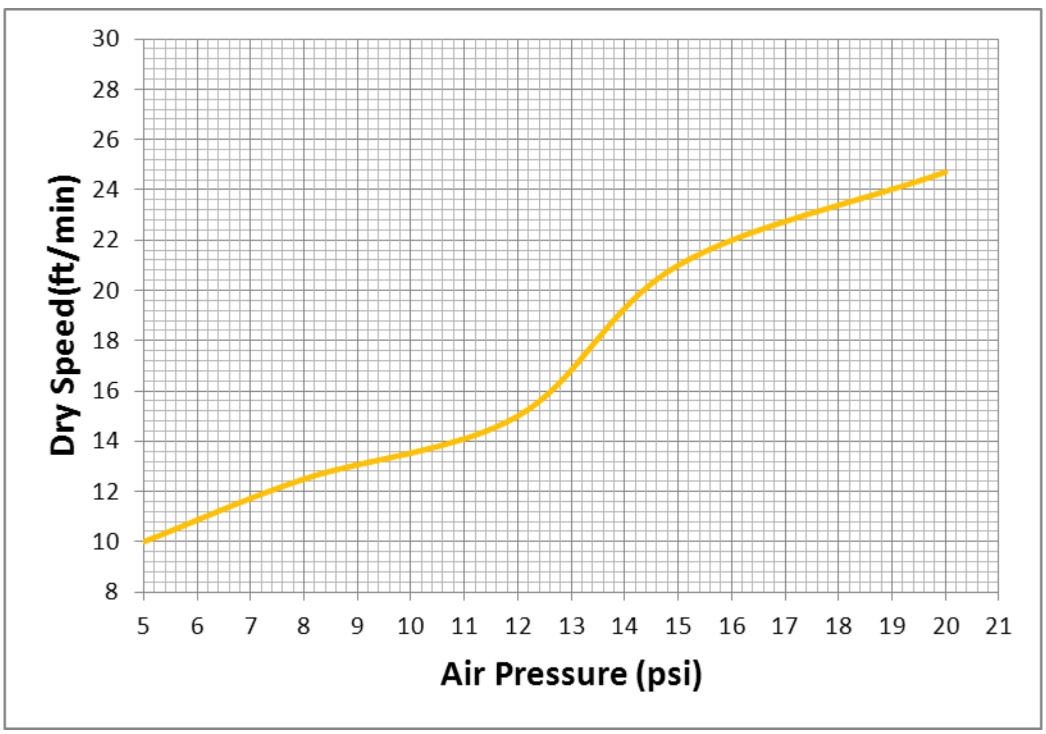


Fig. 3.4. Lab test of relationship between drying speed and air pressure

3.1.2 Vacuum Tests

Our tests verified that the vacuum could collect large size particles. Smaller pieces of old sealant that were removed by a brush were collected as well (Fig. 3.5).

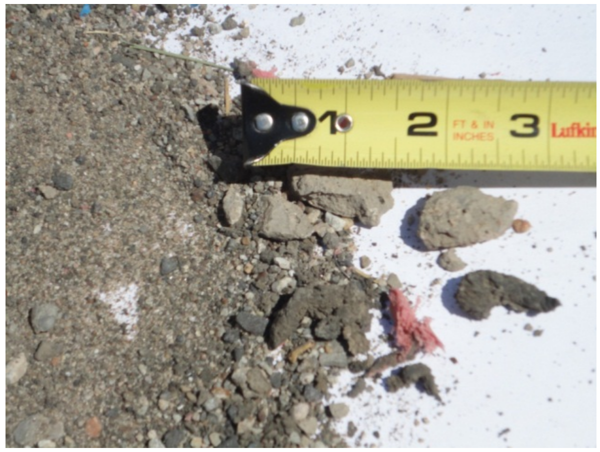


Fig. 3.5. Material collected by vacuum

Another important application of the vacuum unit is that it collects dust while the blade cuts concrete pavement. To compare the vacuum's capability of sucking dust, saw-cut joints on a concrete block were made with the CCD. Without a vacuum unit attached, the running blade yielded a large dust cloud, which could be harmful to human health. With a vacuum unit attached, the dust was substantially reduced while the blade was cutting the concrete surface (Fig. 3.6).

(a) Creating a large dust cloud without the vacuum attachment

(b) No dust created with the vacuum attachment

Fig. 3.6. Comparative test for dust collection from concrete cutting

3.2 Field Tests

3.2.1 Heat Lance Tests

The research team tested the heat blasting effectiveness of the CCD (Fig. 3.7) on location at I-80 eastbound at 13th St. in Omaha, Neb. This was a night operation, and due to rain, the pavement was wet. The crew from NDOR-District 2 observed how the CCD was working and tried it out for themselves. The CCD was able to clean the cracks and dry out the moisture fast enough for the following sealing group. Because the pavement was wet, it was easy to see the heat blasting at work as it dried out the pavement. From this test, feedback was received in two basic areas: 1) the CCD was too heavy to use continuously for more than an hour; and 2) the area dried by the heat lance was not wide enough for sealant to be applied.

Fig. 3.7. First field test for the second version of heat lance at highway I-80

The second test was conducted with the same NDOR-District 2 group. The crew was satisfied with the modifications to the CCD that had been made based on the feedback from the previous test (Fig. 3.8). It was much more comfortable for them to use. With the wider nozzle dispersing heat over a wider area, it was determined the temperature from the heat lance would need to be higher, which was a main reason for the third generation of heat lance design (See Section 2.1).

Fig. 3.8. Second field test with the modified ergonomic design of CCD

3.2.2 Routing Tests

From February to March 2013, several field tests had been conducted in six NDOR districts when they cleaned and sealed cracks on highways during the sealing season (Fig. 3.9). The main purpose of the NDOR field tests was to compare routing and air blowing functions of the CCD with the current NDOR practices of air blowing, heat lancing and routing. Quantitative data and users' feedback were collected during the field tests.

(a) CCD test

(b) Current conventional router comparison test

Fig. 3.9. Field tests with the NDOR crews on highways

The routing function of the CCD was tested in conditions equal to those encountered while using conventional crack cleaning methods. Comparison data between the conventional router machine and the CCD based on the NDOR crew's feedback are listed in Table 3.1. The mechanism that integrates routing/wire brushing and compressed air reduced the crew size by one person. In addition, it was obvious that the CCD would be a far more economical alternative in terms of equipment purchase and maintenance cost and productivity, compared to the conventional router. The CCD is a much safer option as well.

Table 3.1. Field observed and surveyed comparison data between the conventional rotary impact router and the CCD router

	Rotary Impact Router (25 hp)	**CCD Router (1.25hp)**
Estimated equipment cost	$11,500 + routine maintenance cost	$1,500 (expected) + no routine maintenance cost
Average productivity	1.67 miles/day	2.25miles/day
Crew size	7 to 8, including flag person & truck drivers	6 to 7, reduced by one person for air blowing

Strength	Heavy enough, ideal for straight-line cracks or concrete joint	Safe, flexible, easy to load/unload, air blowing function combined
Weakness	Heavy, expensive, difficult for downhill and windy day operations (safety concerns); may create new cracks, not convenient to move	Requires a stronger motor (e.g., 3hp or greater)
Best working conditions	Longitudinal cracks, straight line concrete joint	Random cracks, longitudinal cracks, transverse cracks

Through surveys and interviews with the NDOR crews, we identified that the primary concern with crack cleaning was to shorten the crack preparation time so the following crack sealing group would not need to wait. The conventional rotary impact router's general production rate is 12 to 15 ft/min (Smith and Romine 1993). The measured average productivity of the CCD router during the field tests was 26.1 ft/min, which can significantly improve the overall productivity of the crack sealing process (Table 3.2).

Table 3.2. CCD router production data

Test Sites		Average CCD Working Speed (ft/min)	Crack Type	Version of CCD
1	Palmyra, NE	28.8	Transverse cracks	CCD with increased weight and larger air wand
2	Fremont, NE	22.2	Random cracks	CCD with increased weight and larger air wand
3	Lincoln, NE	22	Old sealant removal from concrete joints	First version of CCD
4	Gibbon, NE	22.5	Longitudinal cracks	First version of CCD
5	Holbrook, NE	36.6	Longitudinal cracks	First version of CCD
6	O'Neill, NE	24.6	Longitudinal cracks	First version of CCD
Average		**26.1**		

4. TECHNOLOGY TRANSFERRING EFFORTS

4.1. Demonstration at Crafco Inc.

In early August 2012, the research team traveled to the Crafco Inc. manufacturing facility in Chandler, Arizona to demonstrate the CCD. Crafco Inc. is the nation's largest roadway maintenance equipment/material supplier. In their testing yard, the following tests were demonstrated: 1) cutting concrete pavement; 2) brushing and routing cracks; 3) heat lancing; 4) vacuuming. The demonstration was successful and the CCD was well received by the Crafco manufacturing and sales teams (Figs. 4.1 and 4.2)

Fig. 4.1. Brushing and vacuuming demonstration at Crafco's test yard

Fig. 4.2. Heat lance temperature measurement by Crafco technical staff

Further, Crafco Inc. has shown high interest in commercializing this product after the Arizona demonstration at their company. NUtech Ventures, a nonprofit research and development technology commercialization company associated with the University of Nebraska-Lincoln, has been working on this technology transfer with Crafco Inc.

4.2. Training and demonstration at the NDOR

Two operation and safety training sessions were conducted for NDOR crews in October 2012 (Fig. 4.3). After the training session, an outdoor demonstration of the CCD was performed. The three attachments (blade, router and brush) installed on the CCD were tested on a precast concrete block and on pavement. A marketing manager from Crafco in Arizona attended the training session and participated in a discussion about commercialization with NUtech Ventures.

Eight units were manufactured and delivered to each NDOR district in Nebraska, along with user manuals, with funding from the NDOR (Fig. 4.4). Heat lance and vacuum devices were demonstrated but not included in the delivered package. NDOR was mainly interested in replacing their current crack preparation methods (i.e., rotary impact router, air blasting and heat lancing) with the CCD's integrated routing and air blasting functions. Thus, routing was the main function tested with the NDOR districts. The performance results can be found in Section 3.2.2.

Fig. 4.3. Operation and safety training for NDOR maintenance crews

Fig. 4.4. Crack cleaning units for demonstration at an NDOR district yard

4.3. Pothole repair for the City of Omaha

Recently a CCD unit was delivered to the City of Omaha road maintenance group for testing in pothole repair. The city's main interest was to test the CCD's ability to cut the asphalt pavement around a pothole area in conjunction with a jackhammer before placing a new patch. If successful, the pothole repair time and physical efforts will be significantly reduced. The test will be completed near the end of this year.

5. CONCLUSIONS

The advanced CCD has been developed from an initial prototype to a multi-functional device with some real merits. After multiple field tests, the research team received much useful feedback from pavement maintenance crews from the Nebraska Department of Roads, the City of Omaha and the nation's largest roadway maintenance equipment/material supplier, Crafco Inc., enabling us to modify and update the design. At the close of this project, the research team concludes major findings as follows:

- Two additional functions of the CCD have been successfully developed, including electric heat lancing and vacuuming, to meet the need for a low-cost effective tool to prepare cracks and joints before sealing/filling. In addition, a routing function was added to the CCD and intensively tested compared to the conventional heavy router.
- The updated CCD was found to offer effective solutions for hot air blowing and vacuuming. The heat lance unit was updated with larger heating capacity and safer operation. Preheating time, most efficient air pressure and drying speed on wet pavement surface were measured. The vacuum design was more effective in conjunction with the running attachment's kicking motion, which directed more debris and particles into the opening of the suction hose. Also, the wider iron guard around the suction opening and the brush added at the bottom could significantly collect more particles and dust – even old sealant.
- An ergonomic shaft design was substantially changed from a curved shaft to a straight forward shape to better accommodate the heat lance unit, the vacuum unit and the rear wheel assembly, and to make them less susceptible to damage.

- Several field tests for routing cracks have been performed on highways throughout the state of Nebraska with NDOR crews in each district. Eight CCD units were prototyped and used at each NDOR district for the entire sealing season in 2012-2013. Positive and promising feedback was collected. The feedback shows that the CCD can be used in conditions equal to those present with current crack cleaning methods; it works well on meandering cracks; its use can reduce the crew size by one person (blowing); it increases production rate; and it offers a safer alternative to conventional methods. Further modifications are currently being made, based on NDOR's feedback and suggestions.
- Crafco shows high interest in commercializing this product after the Arizona demonstration at their company in August. Currently NUtech Ventures is taking care of technology transfer issues.

6. PLANS FOR IMPLEMENTATION

The University of Nebraska is uniquely suited to guide this prototype through the various phases of research toward industry acceptance. The investigators have been working with NDOR in both rigid and flexible pavement applications for several years. Our established partnership with NDOR, the City of Omaha and industry contractors will be invaluable in a number of ways. First of all, the projects partners' input throughout the period of development ensured that a key outcome of this project is practicality. Second, the research team can further utilize a large assortment of test beds to analyze the effectiveness of each prototype. Third, by directly partnering with NDOR, unquestionably the largest user of these types of products within the project's target customer base, it is expected that the product will eventually gain statewide acceptance of the product for use in highway applications. If the device is successfully approved for state projects, it is anticipated that local contractors would also want to own the new device to participate in the state or city projects.

The roads maintenance group in the City of Omaha, NE has shown interest in adopting the device for crack and pothole cleaning and repair. Since a wire brush can simply be replaced with a rotary asphalt cutting blade, the device can rout cracks and cut a pothole area in conjunction with a jackhammer before placing a new patch. The pothole repair evaluation is currently being conducted by the City of Omaha and will be completed by the end of this year.

NUtech Ventures, a nonprofit corporation dedicated to linking companies, entrepreneurs and investors with the University of Nebraska-Lincoln researchers who are driven to develop commercial products or services based on their pioneering research, is currently working with the research team in order to solidify a viable course of action for commercialization. Plans include applying for a patent on the invention of the CCD (pending now) and licensing the technology to Crafco Inc. Crafco Inc. has taken a high interest in the device and agreed to act in an oversight capacity for further development.

Based on the feedback and recommendations from the field evaluations sponsored by NDOR, moderate design modifications for routing cracks were identified as follows:

1) Increase weight (heavier metal block or heavier motor)
2) Increase CFM for air wand (at least 3/8" ID)
3) Use a more powerful motor with larger torque

The research team is currently updating the CCD based on the recommendations above, and the updated version of CCD, which will be close to the commercial version, will be tested again with the same NDOR crews for their final comments. If the test is successful, it is expected that NDOR will replace the current crack preparation practices in all districts with the CCD routing method.

6. REFERENCES

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